What would the world be, once bereft
Of wet and of wildness? Let them be left,
O let them be left, wildness and wet;
Long live the weeds and the wilderness yet.

Gerard Manley Hopkins

Earth will harbour the progeny of humankind
only so long as it continues to succour wilderness

Indo-British Workshop on Biodiversity, February 1993

Biodiversity conservation

forests, wetlands and deserts

Editors
Bob Frame and *Joe Victor* (British Council Division, New Delhi)
Yateendra Joshi (Tata Energy Research Institute)

Tata Energy Research Institute
New Delhi

British High Commission
British Council Division
New Delhi

Suggested form of citing this volume is as follows:
Frame B, Victor J, Joshi Y (eds). 1993
Biodiversity conservation: forests, wetlands and deserts
New Delhi: Tata Energy Research Institute. 153 pp.
[Proceedings of the Indo-British Workshops on Biodiversity, February 1993, New Delhi]

ISBN 81 - 85419 - 03 - 5

Orders for copies may be sent to
Documentation and Information Centre
Tata Energy Research Institute
101 Jor Bagh
New Delhi - 110 003
India

Price
Rs 220/- (within India)
US $42 (overseas)

Printed at Rajkamal Electric Press, B35/9 GT Karnal Road, Delhi - 110 033

Contents

सत्यमेव जयते

S. Z. QASIM

सदस्य
योजना आयोग
योजना भवन
नई दिल्ली-110001
MEMBER
PLANNING COMMISSION
YOJANA BHAVAN
NEW DELHI-110001

November 1, 1993

MESSAGE

The Indo-British Workshop on "Biodiversity" held in February, 1993, was a great success. In this meeting, very distinguished and eminent scientists, academicians, environmentalists and social workers participated. The theme of the workshop was divided into three sectors dealing with: (1) Wetlands (2) Forests and (3) Deserts. All the three sectors are extremely important for India because our country has thousands of hectares of wetland which have not been fully utilised and these hold a great potential for aqua- culture of fish and shrimps and for maintaining the aesthetic value in the region of their occurrence. Similarly, the forests of India have been subjected to a great deal of pressure, and because of intensive deforestation, a lot of ecological problems connected with soil erosion, siltation of rivers and dams leading to floods in different parts of the country, have become widespread. The deserts also form interesting habitat as both fauna and flora of the deserts need special adaptations for their life cycle.

All the three sectors discussed in the workshop have a great deal of biodiversity. In the wetlands, we have large areas of brackish water, freshwater, reservoirs, lakes and backwaters. In these the fauna and flora have become very vulnerable to man-made changes. Similarly, in the forests and desert ecosystems, we have a lot of diversity existing in the plants and animals. Therefore, the maintenance of biodiversity is of prime importance to conserve the great heritage which Nature has provided to a country like India which has diverse agro-climatic conditions. The papers presented and discussions which followed in the workshop have evoked a great deal of enthusiasm towards the preservation of biodiversity.

I am sure the proceedings of the workshop, when published, will provide an excellent record of the rich contributions made during the workshop.

(S.Z. Qasim)
Ph.D., D.Sc.(Wales), F.N.A.Sc.,
F.A.Sc., F.N.A.

From the High Commissioner
Sir Nicholas Fenn

British High Commission
New Delhi
Tel. : 687 2161

2 November 1993

INDO-BRITISH WORKSHOP ON BIODIVERSITY

It is a pleasure indeed to be associated with the publication of the proceedings of the Indo-British Workshop on Biodiversity which was held during February 1993.

The workshop is the second in a series which the British Council Division has organised. The topic has been the survival of the species and the event has brought policy makers, scientists, academics, and development workers together for deliberations on the three different ecosystems.

Conservation and Development are partners in the process of Environmental Protection. Biological Diversity is to be preserved to achieve sustainable development.

I congratulate the organisers and publishers of the proceedings.

Nicholas Fenn

Introduction

British Council Division initiatives in the environment

Bob Frame
British Council Division, British High Commission
17 Kasturba Gandhi Marg, New Delhi - 110 001

The environment has always been part of the activities in India of the British Council Division of the British High Commission, which aims to promote an enduring understanding and appreciation of Britain. Our activities include the management of aid projects as well as workshops, study tours, and training attachments in Britain, usually as part of bilateral aid projects funded by the Overseas Development Administration of the British Government in conjunction with the Government of India.

In recent years these programmes have developed as a result of continuing interest, in Britain and internationally, in the environment. In recognition of this, the British Council in UK established a modest Environment Projects Fund in 1991 to assist in the development of new ideas. India has been fortunate in bidding for these funds and was able to mount the Indo-British Symposium on Climate Change in January 1992. Here, leading Indian and British policy makers, academics, and NGOs (non-governmental organizations) debated the science, impact, and responses to global warming, using the format of the Intergovernmental Panel on Climate Change. The proceedings were published by the Tata Energy Research Institute as a contribution to the debate at the time of the UNCED (United Nations Conference on Environment and Development) in Rio de Janeiro.

This year, the Fund supported a series of Indo-British Workshops on Biodiversity, the main outputs of which are recorded here. In 1994, it will sponsor a similar workshop on environmental impact and research assessment at NEERI (National Environmental Engineering Research Institute) in Nagpur as well as a series of follow-up events on climate change and biodiversity. In the future, we hope that it will continue to support developments in this area and a strategy to enable this is currently being established.

Indo-British Workshops on Biodiversity

Biological diversity (biodiversity) is the variety and variability of plant and animal species on our planet. The number of species is estimated to be between 5 and 50 million, of which only about 1.4 million species have been identified. Developing countries in the tropical zones are rich in biodiversity, but face severe conservation problems in view of their pressing economic and population related problems. The problems in India are no different.

Since the Earth Summit in Rio, the level of debate on biodiversity has increased. Within India, the debate continues but different views are put forward on how biodiversity should be managed and conserved. Britain has substantial expertise in this area and is committed to sharing it with developing countries.

As a means of sustaining debate on biodiversity conservation, the British Council Division organized a series of Indo-British Workshops on Biodiversity in February 1993. The aim was to promote a better understanding of the issues concerning three ecosystems: forests, wetlands, and deserts. Prior to a policy debate in New Delhi, British specialists undertook field visits with Indian teams of experts to examine local biodiversity.

Nine British specialists were invited, along with over thirty senior Indian scientists, policy planners, researchers, and development workers from NGOs involved in the various field visits. Together they worked on increasing their understanding of the biological diversity of the selected ecosystems and the correlation between the need for biodiversity conservation and the compulsions of increased productivity to meet socio-economic demands.

There were three workshops to look at specific ecosystems.

Forests. Field visits (1–4 February) to the Western Ghats, followed by technical discussions (5–6 February) in Bangalore.

Wetlands. Field visits (1–7 February) to the wetlands at Bhitarkanika, Orissa and East Calcutta, followed by technical discussions (8–9 February) in Calcutta.

Arid deserts. Field visits (2–7 February) to Jaisalmer district and the Indira Gandhi Canal Project near Bikaner, followed by technical discussions (8–9 February) in Jodhpur at the Central Arid Zone Research Institute.

These were followed by a policy workshop in New Delhi on 11 and 12 February to discuss feedback on the regional workshops with additional sessions covering survey and research needs, field action programme, and areas of collaboration.

This enabled greater interaction between field workers and policy makers and although much of the debate followed familiar ground it was able to approach some problems, notably monitoring techniques, from a different perspective.

In total, over seven hundred people attended the workshops and a great deal

of opinion, often controversial, was shared. It is doubtful if any significant breakthrough could have been made or any major conclusions reached in so short a time. However, we believe that some preconceptions have been shifted and a greater understanding of the difficulties was achieved. As *Down To Earth* magazine pointed out when reviewing the workshops, there are differing views on biodiversity management, which often get entrenched in the North–South dialogue. One of the major issues that featured strongly was the importance of people's needs in the management of natural resources and the technical solutions presented for conservation. Although there is unlikely to be an immediate resolution to this problem, it remains important to continue to look at these issues.

New initiatives

There are several initiatives that have followed UNCED and it is too early to comment on their implementation. The British DOE (Department of the Environment) announced the Darwin Initiative, which aims to support the implementation of the Biodiversity Convention by deploying the strengths of the United Kingdom in assisting with the conservation and sustainable use of biodiversity and national habitats. The initiative is targeted at British institutions currently engaged in biodiversity and is managed by the DOE. There are many other programmes coming into operation funded by the Government of India including those with bilateral and multilateral assistance. A follow-up conference to UNCED, called Partnerships for Change, was held in Manchester in September 1993, where NGOs discussed follow-up to the UNCED.

On a much smaller scale, the British Council Division is supporting Indian organizations in collaborative research on biodiversity as part of its continuing interest in the environment. This includes joint workshops with the Asian Wetland Bureau on management issues relating to Oxbow lakes on Floodplains. It is also intended to assist in running courses with the Wildlife Institute of India, Dehra Dun, on monitoring for conservation and ecology. This will assist field conservationists, researchers, and NGOs to increase their understanding of techniques and enable them to adapt them to the Indian situation.

Proceedings

All the participants in the field visits and to the workshops were invited to submit papers, giving data on the ecosystems and the ways in which biodiversity was being exploited or conserved. Some information is available through existing sources though much of the interdisciplinary work that we sought to encourage was not previously available. It is not possible in this volume to reproduce all the contributions that were made or to synthesize all the debate into a cohesive

whole. We have attempted, therefore, to pull out the main themes and present these through some of the papers and summaries of the discussions. We regret that we have not been able to present more of these in the space available but we hope that those given will stimulate further debate and study of the main issues.

Full versions of all the papers submitted to the workshop organizers are available from the authors or through the relevant regional office of the British Council Division in India. A list of contact addresses and participants forms a part of this volume.

An overview of biodiversity conservation is given from both Indian and British perspectives before reviewing the specific ecosystems and the summary of the conclusions from the regional workshops. Finally, we have taken the various aspects of the round-up worshop; we present these as a possible way forward. However, much remains to be done and we look forward to making our contribution to that process in the future.

Acknowledgements

The British Council Division wishes to acknowledge the valuable support it received in planning and running the whole event from the Ministry of Environment and Forests, and in particular from Samar Singh, D K Biswas, and K P S Chauhan. Financial support was gratefully received from the British Council's Environment Projects Fund and from Standard Chartered for the Indo-British Workshops on Biodiversity.

The editors are very pleased to express their appreciation to all of their colleagues who gave such generous assistance in planning, implementing, and ultimately recording such a complex feat of organization. The list is a long one and prone to omission. However, we must mention Somen Dhar, Eric Edmonds, G S Gujral, Sunita Kripalani, Vivek Mansukhani, Leela Negi, Jayanthi Rajgopal, Kartar Singh, K Swaminathan, and Goodie Vohra as well as our colleagues in Information Resources and Administration in Calcutta, Delhi, and Madras. There were also many hands at play in Britain, in our SCTD, DPX, and OVS, as we know them. We should also not forget other colleagues throughout India for 'Doing the Needful' as required nor our friends at TERI for picking up so many diverse pieces and instilling some form when we lost sight of it. Especial thanks are due to Amrita Achanta for giving the entire text a 'once-over', to Eashwar for scrutinizing it, and to Radhakrishnan for typesetting it.

Finally, we must thank all the many speakers, participants, organizers, and administrators whose enthiusiasm and hard work ensured that all our plans were not thwarted by the many external events that conspired against us. We hope that all the effort will enable us to have made some lasting contribution, however small.

Biodiversity perspectives

Conservation of biodiversity

D N Tewari
Indian Council of Forestry Research and Education
Dehra Dun - 248 006

Introduction

Biodiversity (biological diversity) is the variety and variability of plant, animal, and microorganisms. Our planet's essential goods and services depend on the variety and variability of genes, species, populations, and ecosystems. Biological resources feed and clothe us and provide housing, medicines, and spiritual nourishment. The current decline in biodiversity is largely the result of human activity and represents a serious threat to human development.

The loss of the world's biological diversity, mainly from habitat destruction, over-harvesting, pollution, and inappropriate introduction of foreign plants and animals, is continuing. Efforts are needed to conserve and maintain genes, species, and ecosystems with a view to sustainable management and use of biological resources. *In situ* protection of ecosystems and *ex situ* conservation of biological and genetic resources can help in using biological resources sustainably. Biotechnology has the potential to develop modified plants, animals, and microorganisms.

Although tropical forests only cover about 12% of the total land surface of the globe, they contain at least 50% – and probably 90% – of all the species on earth. Ninety per cent of the world's non-human primates are found only in tropical rain forests, along with two-thirds of all known plants, 40% of birds of prey, and 80% of world's insects. As a whole, tropical forests could contain between 2.5 million to 5 million species, of which less than half a million have been identified to date.

The complexity of the interactions between species in their natural ecosystems is such that any modification to these ecosystems is likely to lead to the loss of species or, at least, of genetic variants. The full diversity of forests could never be protected in botanical gardens, greenhouses, or gene banks.

Biodiversity in India

The meeting ground of three major global biogeographic realms, the Indo–Malayan, Eurasian, and the Afro-tropical, India is one among the world's top twelve mega-diversity nations. India with its geographic area of about 329 million hectares has almost all the climatic conditions and ecological zones found in different parts of the world, ranging from perpetual snow cover to eqatorial and tropical conditions; from mangroves to humid tropics and hot and cold deserts; and everything in between. The plant wealth of India is about 45 000 species, which constitutes roughly 12% of the global plant wealth. The flowering plants alone number about 15 000 species (16% of the global wealth of flowering plants) and nearly 33% of these are endemic, located chiefly in 26 endemic centres in India. Nearly 1000 species are endangered.

The animal wealth of India is some 68 371 species, which includes 60 000 insects, 1693 fish, and 372 mammals. The rate of endemism is 33% in reptiles and 62% in amphibians. There are no estimates of India's marine life although it has a coastline over 7500 km long, with a shelf zone of over 45 million hectares and an extended economic zone of over 201 million hectares.

W G D P (Western Ghat Development Programme)

The Western Ghats hill ranges stretch to about 1600 km, more or less parallel to the coast of Maharashtra, starting from the mouth of river Tapti in Dhule district of Maharashtra and ending at Kanyakumari, the southernmost tip of India in Tamil Nadu. The region covers an area of 160 000 km^2, supporting a population of 38.85 million (1981 Census). For delineation of the area for coverage by the WGDP, the criteria of elevation (600 metres above the mean sea level) and contiguity with *taluka* (a territorial administrative unit) have been adopted.

The region generally receives 2000 mm to 7000 mm of rainfall. Most of the rivers in peninsular India have their origin in the Western Ghats. The Godavari, the Krishna, the Kaveri, the Kali Nadi, and the Periyar are important to more than one state. These water resources have been harnessed for irrigation and power. Thirty per cent of the area of the *ghat* region is reported to be under forests. The region is also a treasure house of plant and animal life. Traditional horticulture crops in the region are arecanut (betelnut, *Areca catechu*) in the hills and coconut on the coast, along with mango and jackfruit. Tea, coffee, rubber, cashew, tapioca, and potato are the other important plantations/crops of the region.

The ecological and environmental problems of the area include increasing pressure of population on land and vegetation; submergence of forest areas under river valley projects; encroachment on forest lands; clear felling of forests for

raising tea, coffee, rubber, and other plantations; mining operations, soil erosion, and land slides; shifting cultivation; and declining wildlife population.

A separate Western Ghats Development Programme was launched in 1974/75 as a part of the programme for the development of hill areas.

During the Fifth Five-Year Plan, the WGDP emphasized economic well-being of the population in the hills and exploitation of the resources of the region. The main programmes during the Fifth Five-Year Plan consisted of activities in the areas of horticulture, plantation, afforestation, minor irrigation, animal husbandry, and tourism.

The Sixth. Plan stressed the need for a balance in emphasis between beneficiary-oriented and infrastructural development schemes, keeping in view the vital importance of ecological restoration and conservation. During the Sixth Plan, a watersheds development programme was taken up on a pilot basis.

Apart from the shift in the emphasis from beneficiary-oriented schemes to eco-conservation and eco-development, a notable step initiated by the Planning Commission during the Sixth Plan was the involvement of universities and research institutions located in the Western Ghats region in the programme.

The following guiding principles were followed for the WG.DP during the Seventh Plan period.

- Maintenance of ecological balance essential for the life-support system.
- Preservation of genetic diversity.
- Restoration of the ecological damage caused by human interactions.
- Creation of awareness among the people and educating them on the far-reaching implications of ecological degradation and securing their active participation for the eco-development schemes.

Endangered species

'Red data' plants of the Western Ghats include 586 species. The number of animals in the endangered list includes 10 mammals (details in Annexure 1). A number of primitive tribes require socio-economic development support.

Scientific research

It is desirable to undertake long-term research into the importance of biodiversity for the functioning of ecosystems and the role of ecosystems in producing goods, environmental services, and other values supporting sustainable development, with particular reference to the biology and reproductive capacities of species and ecological conditions necessary for biodiversity conservation. Keeping this in view, ICFRE (Indian Council for Forestry Research and Education) has established 309 preservation plots throughout the country. However, there are only 7 such preservation plots in the Western Ghat area (Annexure 2).

For getting reliable data, it is desirable to establish about hundred preservation plots in the area of appropriate size to carry out scientific and technological research.

Biodiversity action plan

Recently, the United Nations Environment Programme has constituted four Panels to deal with

- priorities for action for conservation and sustainable use of biological diversity and agenda for scientific and technological research,
- evaluation of potential economic implications of conservation of biological diversity and its sustainable use, and evaluation of biological and genetic resources,
- technology transfer and financial issues, and
- modalities of a protocol for transfer and handling of any living modified organisms resulting from biotechnology.

I hope that this Seminar will especially debate on the following issues.

- Management-related activities for conservation of biodiversity.
- International and regional co-operation and co-ordination.
- Means of implementation of various projects for conservation, eco-restoration, and sustainable management of the Western Ghats.
- Identification of institutions for carrying out socio-economic and conservation studies.
- Systematic sampling designs for data collection, monitoring, and evaluation of results.

Annexure 1. Endangered mammals

1 Loris (*Loris tardigradus*)
2 The lion-tailed macaque (*Macaca silenus*)
3 Nilgiri langur (*Presbytis johni*)
4 Mouse deer (*Tragulus memmina*)
5 Four-horned antelope (*Tetracerus quadricornis*)
6 Indian gaur (*Bos gaurus*)
7 Nilgiri tahr (*Hemitragus jemlahicus hylocrius*)
8 Brant Malabar squirrel (*Ratufa indica*) or Indian Giant squirrel
9 Malabar civet (*Viverra civettina*)
10 Fishing cat (*Prionailurus viverrinus*)

Annexure 2. Preservation plots in the Western Ghats area

Forest type	*Division*	*Range/block/ compartment*	*P.P.no.*	*Year of establish-ment*	*Natural or planted*	*Area*	*Longitude*	*Latitude forest type*	*Description of*
Karnataka									
1A/C4	Yellapur	Yellapur		1932	Natural	21.85	74°43'00"E	14 ° 43'00'N	West Coast tropical evergreen forest
1A/C4	Sirsi	Siddapura/Kodakani	5	1942	Natural	12.85	74°52'00"E	14° 17'00N"N	West Coast tropical evergreen forest
1A/C4	Sirsi	Siddapura/Kathlikan Harlu	11	1942	Natural	7.59	74°47'00"E	14 °16'00"N	West Coast tropical evergreen forest
1A/C4	Sirsi	Sirsi	9	1942	Natural	7.28	74°51'00"E	°37'30N	West Coast tropical evergreen forest
A/C4	Mangalore		1	1935	Natural	6.07	74°50'00"E	12°51'00'N	West Coast tropical evergreen forest
Tamil Nadu									
1A/C3	Nilgiri South Cairn Hill		2/67	1967	Planted	0.07	76°40'00" E	11°23"00"N	Southern Hilltop tropical evergreen forest
1A/C3	Nilgiri South Cairn Hill		1.67	1967	Planted	0.27	76°40'00"E	11°23"00"N	Southern Hilltop tropical evergreen forest

Conservation and development: a United Kingdom perspective

Ronald Kemp
12 Westview Rd, Warlingham, Surrey
Great Britain CR6 9JD

The UK is a small country, intensively occupied, with a long history of agricultural and industrial development. Conservation of Britain's biodiversity is maintained within managed ecosystems, in association with productive use of the land, and with the development of forest resources, based on scientific research, surveys, and monitoring.

Scientific forest management in India developed in close association with concern for the environmental values of the natural forests, including the diversity of native plants. It was born, appropriately, at the hands of medical doctors, such as Dr Hugh Cleghorn of the Madras Medical Establishment, whose interest in the plants was no doubt stimulated by the centuries-long traditions of India's ayurvedic physicians. Stimulated by reports on the need for forest conservation, by Dr Alexander Gibson and others, the British Association for the Advancement of Science, at its meeting in Edinbugh in 1850, set up a committee to consider the probable effects of the destruction of tropical forests. The Committee's report, delivered in 1851, drew particular attention to the importance of the forests in the mountainous regions of the Western Ghats for 'the preservation of the springs which feed the rivers, on which the fertility of the land and the prosperity of the people are so essentially dependent'.

The main author of the report was Dr Cleghorn, whose contribution drew particular attention to advances in the medical botany of the Indian forests, and to the potential value of the great variety of gums, dyes, resins and oils from the native trees and other plants, which he listed by their scientific names. At the same time, he pointed out that 'various others possessed of equally valuable properties would probably be discovered by a more careful examination of those forests'. Thus, he identified what we would now refer to as the 'options values' of the forest biodiversity. Seven years later, in submitting the First Annual Report on Forest Operations in the Madras Presidency, he attached a draft of the *Manual*

of Indian Botany, then in preparation. His report also acknowledged the receipt of a set of named Indian plant specimens from Kew as the nucleus of a 'proposed herbarium of reference' for India.

The scientific studies initiated 150 years ago have been maintained and developed by many distinguished Indian biologists, whose contributions to biosystematics and other essential fields of conservation biology are well represented in these workshop proceedings. Their concern for biodiversity conservation found expression in India's National Plant Conservation Action Plan (1983) and the National Conservation Strategy and Policy Statement on Environment and Development (1992). However, the past 150 years have also seen the growth in population and the loss of forests, which, in combination, form the greatest challenge to those responsible for the conservation and management of India's biodiversity. That challenge can only be met by the most efficient use of the natural resources of land and forests, based on more comprehensive knowledge of the composition of the biodiversity, and interactions in the functioning of the ecosystems. This scientific research must receive the strongest international support, and is a proper subject for intensified Indo-British collaboration.

■

Monitoring biodiversity

F B Goldsmith
Ecology and Conservation Unit, Department of Biology (Darwin)
University College London, Gower Street
London WC1E 6BT

If we accept that the preservation of diversity, in all its forms, is important, we must introduce monitoring procedures to ensure its maintenance. Here, there is only space to deal with the general principles but I have recorded my views and details of techniques more extensively elsewhere (Goldsmith 1991, 1993).

We must monitor to record the integrity of sites such as nature reserves and national parks especially as so many are being threatened around the world. This is usually referred to as SIM (site integrity monitoring).

Secondly, there is a need to monitor to ensure that the quality of such sites is maintained. This is usually referred to as SQM (site quality monitoring).

Thirdly, so that we can record the long-term ecological effects of climatic change.

Fourthly, to be able to detect the effects of, for example, over-grazing, pollution, irrigation, or salinization.

Fifthly, to record changes in the numbers and distribution of rarities, such as endemic plants, orchids, sandgrouse, or the Great Indian Bustard.

Finally, to keep a tally of the richness or diversity of the biotopes that we value.

Some definitions

Unfortunately, a considerable amount of jargon is involved in this subject and it may be useful to clarify the meanings of some words here.

Survey is a recording at one time.

Surveillance is repeated surveys.

Monitoring means repeated recording with clear objectives, using a standardized approach and rules for stopping.

Census involves repeated recording of a single species including fluxes such as births and deaths.

In practice, the meaning of these words overlap but I think that it is worthwhile for ecologists, and other scientists to try and be precise.

A precise definition of monitoring

One-sentence definitions are difficult to agree upon but the following should be considered when trying to formulate one.

- Clear objectives.
- The extent to which the recording meets pre-set standards or expectations, in our case the maintenance of biodiversity.
- The use of standardized methods of field recording.
- The use of standardized, statistically valid, methods of analysis.
- Rules for stopping—sometimes called criteria for termination.

Establishing priorities

Before rushing out to monitor valued ecosystems, one first needs to establish priorities, if only because it is difficult to record everything. The following need to be considered for both biotopes and species.

1 *Conservation evaluation.* Species of international importance take priority over those of national importance. These in turn take priority over those of regional or state importance, which take priority over those of local importance.

2 *Sensitivity.* This reflects the inherent sensitivity of some species or biotopes. Sensitive species and biotopes should take priority over more robust ones.

3 *Vulnerability.* This reflects the resilience of some species and biotopes to external forces such as desiccation, salinization, overgrazing, or pollution.

4 *Simplicity.* If the monitoring is easy to carry out, it is more likely to be conducted than otherwise. Also, it is more likely to be continued when staff change or funding becomes difficult.

5 *Cost effectiveness.* Similarly, inexpensive monitoring programmes are more likely to run until completion than expensive ones.

In order to evaluate the biotopes or species being studied, it is necessary to have extensive survey data (a subject in its own right which, for obvious reasons, cannot be covered here; see, for example, Goldsmith 1974), and data for other comparable areas to set the target one in context. Estimates of manpower and costs are important as is information about possible techniques of recording and data analysis (again, these cannot be covered here but can be found in books on vegetation survey, remote sensing, statistics, and other forms of data analysis).

Monitoring as a self-fulfilling activity

As monitoring usually only starts a few months before development takes place or an area is designated, the initial baseline survey is usually rushed and the

taxonomy of the area is not completely known. Consequently, subsequent monitoring turns up additional species and locations for existing species (see Figure 1). Thus diversity often appears to increase after a land-use change or 'development' takes place.

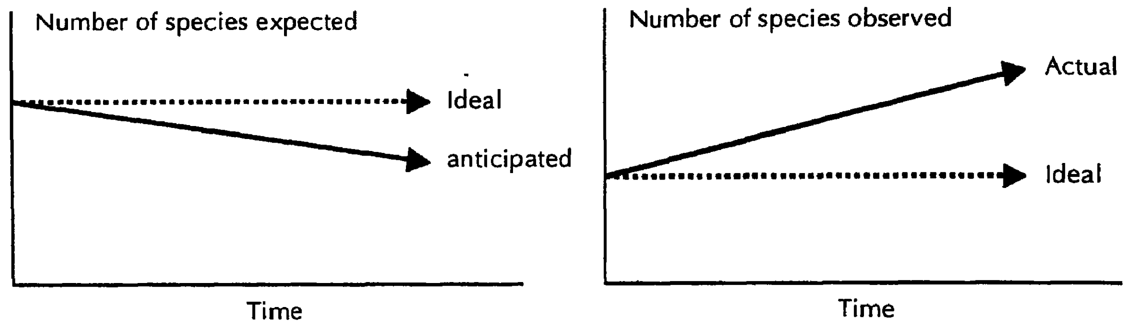


Figure 1. Monitoring as a self-fulfilling activity

This has been shown so frequently that I am surprised that every potential developer does not insist on setting up a monitoring system!

A case-study

Biodiversity can vary from one taxon to another within the same geographical area. This is shown in Table 1, which is based on a study carried out by the Conservation Course at University College London in Southern Spain in 1992. Six habitats on *rana* (wide plains of alluvial material) were investigated. The area has cold winters and hot, dry summers and about 550 mm of precipitation annually.

Table 1. The number of species in Dehesa vegetation, Cabaneros Natural Park, Cuidad Real, southern Spain (Conservation Course 1992).
Note. Totals represent the total number of species for the biotopes and not the sum of the numbers recorded in the sample quadrats.

	Number of species			
Site	*Plants (16 x 16 m)*	*Butterflies (20 x 20 m)*	*Birds (Point counts)*	*No. of plant endemics*
Woodland	23		22	3
Cistus scrub	29		21	4
Wet Cistus	23		22	6
Grassland ploughed 1988	27	5	26	0
Grassland ploughed 1991	12	6	12	1
Overgrazed	9	low	9	0
TOTAL	182	50	54	24

Flowering plants, butterflies, and birds were recorded using 16 × 16 m quadrats, 20 × 20 m plots, and point counts respectively. Nineteen recorders were involved. Absent values for butterflies are due to several wet days in the 10-day study period. This indicates another problem encountered when actually collecting data. The table also shows that the number of species in the plots may not be a good predictor of the number in the total area. Vegetation structure and time since disturbance both appear to have some effect on diversity. One of the grasslands was particularly rich probably due to disturbance that prevented any species becoming dominant. The table also shows the number of endemic plant species recorded for each vegetation type, it being assumed that these are more valuable than others. The number of endemics cannot be predicted on the basis of biodiversity.

Conservation managers have options as to what combination of habitats they wish to preserve and the table reminds us that value judgements have to be made when deciding on the optimal management for areas such as this (Goldsmith 1974). There are usually trade-offs between the main taxonomic groups, for example, plants versus birds. The managing authority has to decide whether all species are of equal value. Those recorded here included white stork, red kite, black and griffon vulture, booted and imperial eagle, red-footed falcon, lesser kestrel, and little and great bustard. If we value high diversity, it is imperative that we establish systems for monitoring it at the level of species, population, site, reserve, national park, state, and nation. Different techniques are appropriate to different taxa—there is no space here to describe them but the references give further details.

References

Conservation Course. 1992
Dehesa: its potential for conservation.
London: University College. 64 pp.
[Discussion Paper in Conservation 56]

Goldsmith F B. 1974
Evaluating nature, p. 233–246
In *Conservation in Practice*, edited by Goldsmith F B and Warren A
Chichester, UK: Wiley. 474 pp.

Goldsmith F B (ed.). 1991
Monitoring for Conservation and Ecology.
London: Chapman & Hall. 275 pp.

Goldsmith F B. 1993
Monitoring for Conservation, p. 241–253
In *Conservation in Progress*, edited by Goldsmith F B and Warren A
Chichester, UK: Wiley. 364 pp.

Forests

Forest ecosystems

S Shyam Sunder
2989/D 12th Main, HAL 2nd Stage, Bangalore - 560 008

The team started its itinerary at the Institute of Forest Genetics and Tree Breeding in Coimbatore, on the afternoon of Monday, 1 February 1993, and finished it in Bangalore at 10.30 p.m. on Wednesday the 3rd. The range of experiences extended from tissue culture laboratories of the Institute to discussion of tribal needs and traditional wisdom with representatives of the Toda people in the Nilgiri Hills. Along the way, we had many hours on the road, few but fascinating hours in the forest, and continual discussions of the issues related to biodiversity conservation. Unfortunately, with so much to see, and such a crowded programme, some items - particularly at the latter part of the planned tour - had to be omitted.

The team was impressed by the excellent choice of the Nilgiri Hills as the main area to be visited, because it encompasses such a wide range of forest types and ecosystems, including grassland areas, and such a wide range of relevant problems in a limited geographical area. The team would like to record its appreciation of the excellent arrangements made, and the hospitality received, throughout its visits in Tamil Nadu and Karnataka. This has enabled the various specialists in the group to identify key issues and principles, which might be the subject of further discussion in the workshop. This brief report is based on the views of the entire team, and is focused on the subject areas and not on particular sites visited. These have served as a valuable case-study, and a catalyst to discussions on broader issues.

The key points that have emerged are valuable for their applicability throughout the region of the Western Ghats and indeed to forests elsewhere in India. We have attempted to summarize them under 12 main points. These encapsulate the views of the team, but do not attempt to cover the detailed specialist knowledge and judgements that went into their formulation.

1 Increased production of fuelwood, fodder, green manure, building materials, and all the other goods traditionally supplied from forests is an essential prerequisite to conservation of forest-based biodiversity. This is the only realistic strategy to avoid further loss or drastic modification of the remaining well-preserved ecosystems, both forests and grasslands.

2 Increased efficiency in the use of land, and of genetic resources comprising trees and other plants, is a necessary condition for the conservation of remaining areas of natural forests. This should involve the selection and conservation of the most productive provenances and seed sources, and associated development of seed banks, genetic improvement programmes, propagation technologies, and related research.

3 In view of the very wide range of the extent of forested areas, forest types and plant communities, with their associated fauna, that need urgent action to conserve them, it is essential to set priorities for the selection of the 'core' conservation sites and to identify species and communities that are most threatened. This prioritization must be based on sound and, as far as possible, quantifiable data, drawing on the substantial amounts of existing information requiring compilation and analysis, and supplemented by intensified surveys, inventories, and research, targeted to fill important gaps in knowledge.

4 Increased pressures from expanding populations and their development needs demand increasing efficiency in management of natural resources, including biodiversity, both *in situ* and *ex situ*. This requires more complete scientific data on the composition and functioning of natural ecosystems, including the vital role of insects, other invertebrates, and microorganisms. Conservation of entire communities and ecosystems is the only realistic means to conserve most of the forest biodiversity.

5 Whereas the flora, and particularly the higher plant species, have received considerable attention, there is almost complete lack of information on the economic potential and ecological role of functional groups of insects, which undoubtedly have key roles in forest ecosystems and in the possibilities for *in situ* conservation as well as in the sustainability of production in managed forests.

6 *Ex situ* conservation technologies, both in the controlled environments of laboratories as seed banks, and in the field as arboreta, are important tools to supplement *in situ* conservation strategies. They require greater attention to the development of techniques for storage and propagation, and to the studies of individual species.

7 Databases and information systems for more efficient storage, handling, analysis, and interpretation of information are needed both to exploit the data already available at many scattered locations, and to assist in the planning and execution of further surveys and inventories. Increased compatibility and integra-

tion of databases is important in both strategic and operational levels for effective conservation programmes. The excellent co-operative action already undertaken provides the base for further development.

8 Information systems designed to assist the incorporation of the knowledge possessed by local people regarding the occurrence and uses of forest plants and animals, as well as scientific data, are especially valuable in conservation strategies.

9 Involvement of local people in the planning and management of the use of forest resources, particularly related to trees, shrubs, and herbs of medicinal or other cultural importance, may be important in securing their support for the conservation of the forest as a whole.

10 Some areas in the Nilgiri Hills, because of the compression of several different forest types into a very limited space (e.g. Kunjapparai), may offer special opportunities for biodiversity studies covering a range of habitats.

11 Intensified training is needed in all fields of data collection, scientific sampling, analysis, interpretation, and the handling and conservation of both living collections and specimen material, to provide the necessary skilled manpower.

12 Increased international exchange of information and experience would be a valuable stimulus and aid to both research and training programmes.

Research options and priorities for conservation of biological diversity in the Western Ghats

K P S Chauhan
Ministry of Environment and Forests, Paryavaran Bhawan, C G O Complex
Lodhi Road, New Delhi - 110 003

Introduction

Conservation of biological diversity has assumed great importance recently not only for maintaining the ecological balance, but also for sustaining human welfare through the use of biological resources.

The Western Ghats is among the ecologically richest regions of India, next only to the Himalaya in the diversity of its biological species (Gadgil 1984). Its singular geological history, and the relatively limited width of its hill ranges, which are separated by narrow passes, have contributed to a high degree of endemism (Ahmedullah and Nayar 1987). Its climate and rainfall patterns have produced a variety of ecological niches with unique plant and animal species—of the 15 000 plant species recorded so far, 4000 are endemic to the region, as are 75% of the reptiles and amphibians (Daniels 1992). The Western Ghats is also recognized as a centre of origin of several cultivated plants, the progenitors of pepper, cardamom, ginger, turmeric, mango, jackfruit, 'ragi' (*Elusine coracana*), and a variety of other millets (Gadgil 1984). It is a gene centre for several orchid species and also has a high percentage of medicinal plants. Its ecological diversity is represented in the fragmented remnants of the original multi-species *shola* forests. Each such forest is now no more than 20 km^2, which is indicative of the pressures that the region has been subjected to during the last 100 years or more. The region is also rich in iron, manganese, and bauxite ores. The biological diversity of the Western Ghats is not only important in itself, or as the resource base of the diverse human communities who live in the region, but also for maintaining the life-support systems of the peninsular region. A strategy for the conservation and sustainable use of biological diversity has to be integrated, encompassing the inter-linkages between several different facets (Figure 1).

Conserving biodiversity requires steps to protect genes, species, habitats, and ecosystem *in situ*. This can be supplemented by restoring lost species to their

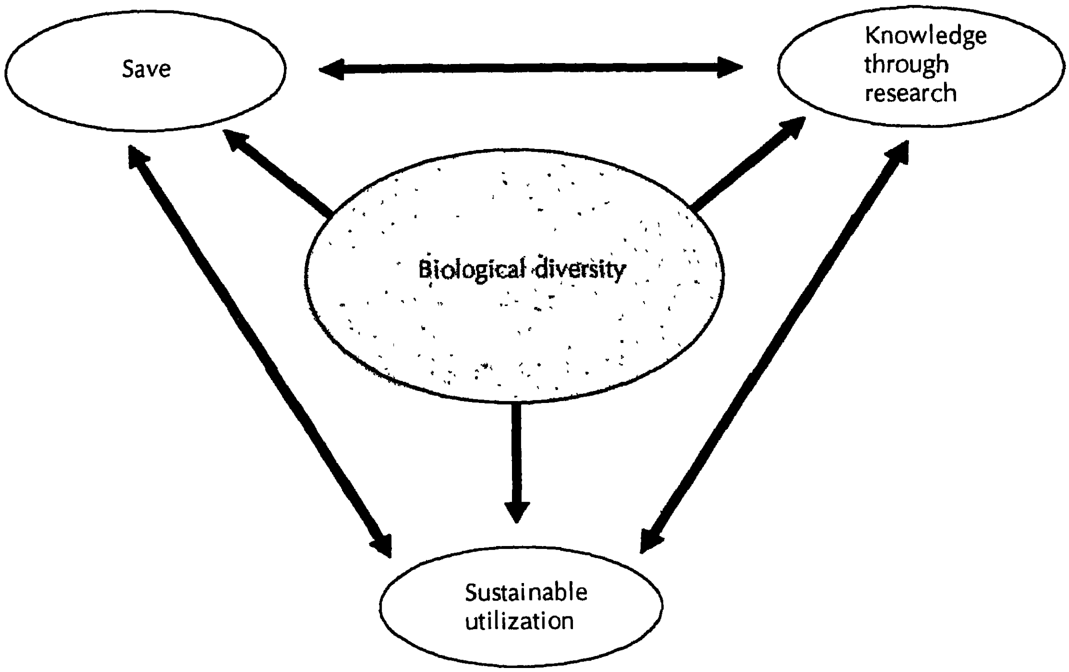


Figure 1. Inter-linkages between facets of biological diversity conservation

former habitats, and by *ex situ* preservation of species in gene banks, botanical gardens, zoological parks, etc. In the long term, a combination of both *in situ* methods, which alone can ensure the continuation of the process of evolution, and *ex situ* methods, is necessary; this will also provide the basis for sustained research. The options that could be considered are given in Figure 2.

Several scientific disciplines are relevant to conservation and sustainable utilization of biodiversity (Figure 3). Considerable information on the diversity of plant and animal species of the Western Ghats forests has been generated by institutions such as the Botanical and Zoological Surveys, the Centre for Ecological Sciences (Indian Institute of Science, Bangalore), the French Institute (Pondicherry), the Kerala Forest Research Institute (Peechi), and local universities. However, much more needs to be done towards recording genetic diversity (of species and varieties); analysing the role and function of the ecological processes of different ecosystems (forests, grasslands, and water bodies); understanding the complex inter-linkages between natural and modified systems; and recognizing and integrating traditional and cultural conservation practices. Therefore, the immediate research need is to develop baseline data that could be integrated with the GIS (geographic information systems) network. This is schematically outlined in Figure 4. Such information would be valuable both for environmental managers and as an educational input for the general public.

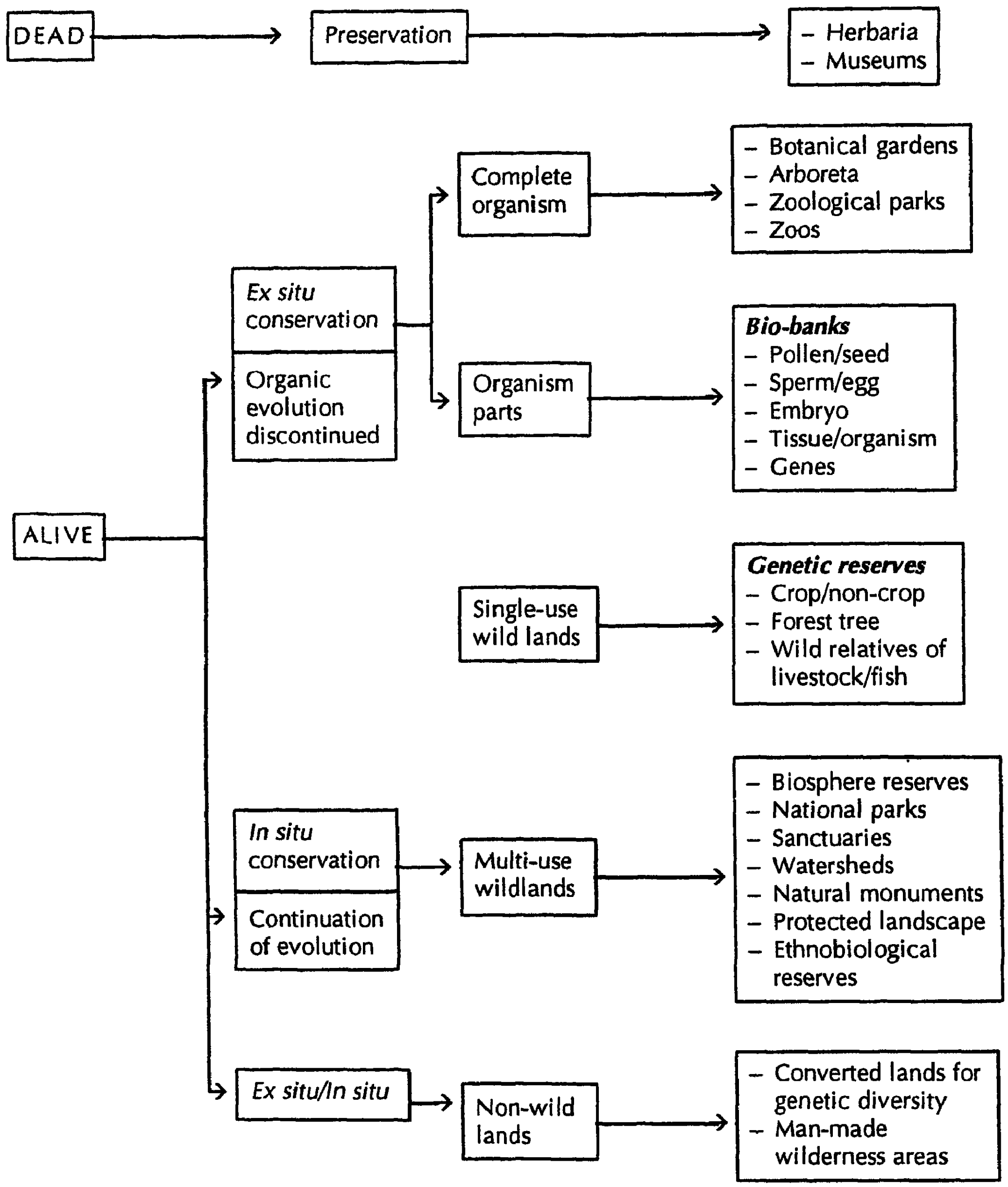


Figure 2. Options for biological diversity conservation

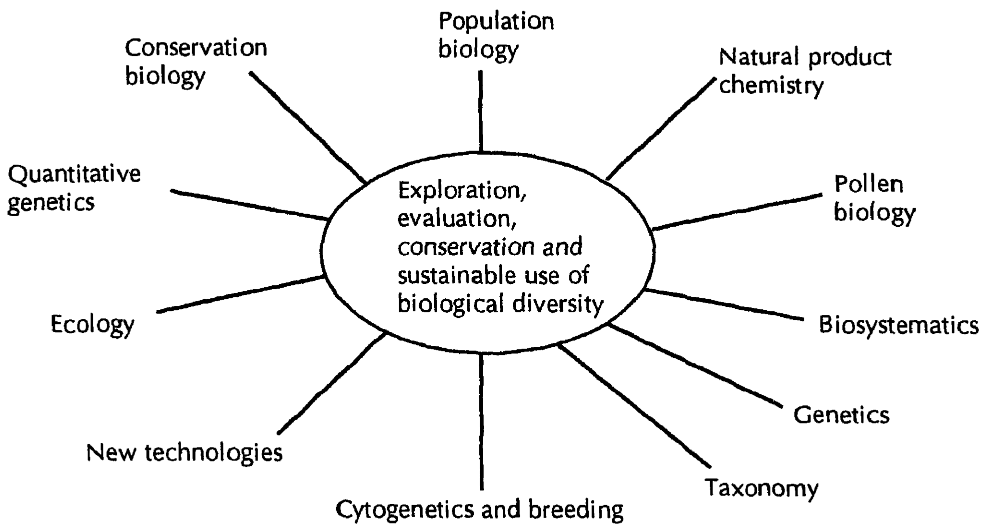


Figure 3. Different scientific disciplines involved in conservation of biological diversity

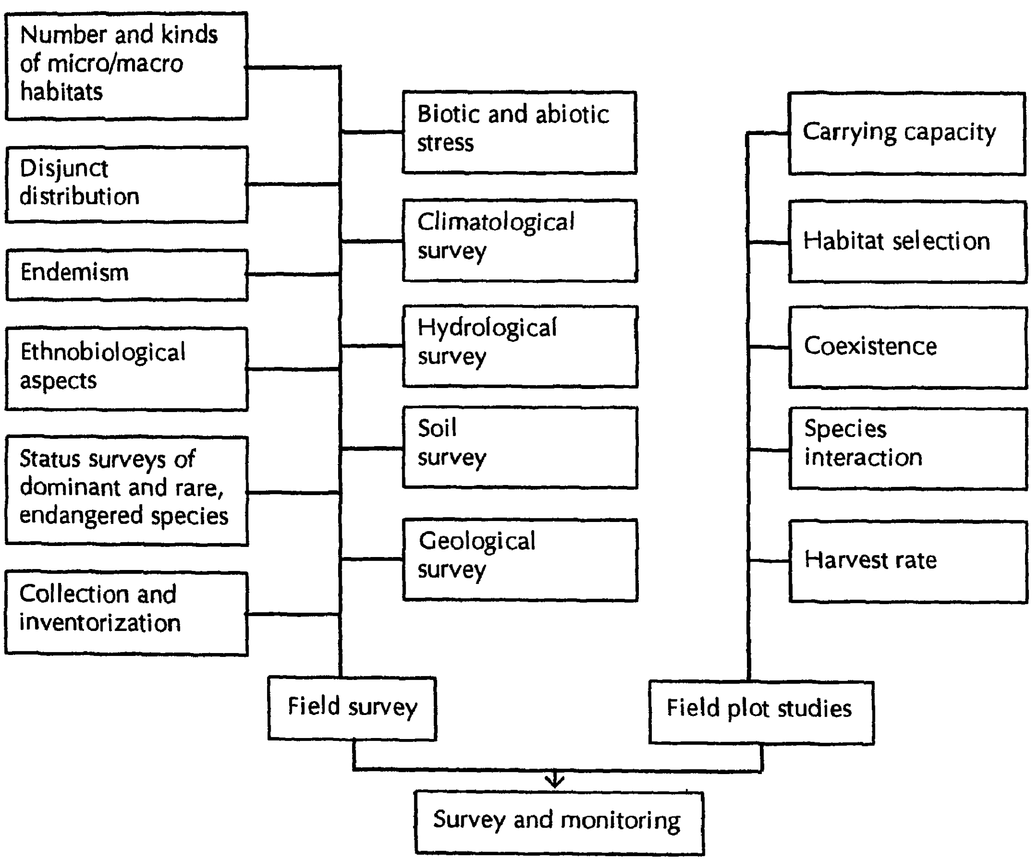


Figure 4. Baseline data for development of GIS (geographical information systems)

An in-depth understanding of the unique biological diversity of the Western Ghats is vital to ensure its conservation and its sustainable and equitable use. For this, we also need to identify those areas that should be set aside as 'last resorts', to be conserved in their pristine purity (Anon. 1993) – forested watersheds and sacred groves for example – and those areas where the productivity of the ecosystem could be utilized for improving human welfare.

Priority areas for research

In developing a scientific management strategy for conserving the biological diversity of the Western Ghats, it is necessary to prioritize the research activities that will provide the necessary information support. Nine priority areas are outlined, which are listed below.

1 Survey
2 Composition, structure and function of ecosystems
3 Monitoring
4 Sustainable use
5 Valuation
6 Integration of traditional knowledge and skills
7 Social, economic, and cultural factors
8 Developing restoring technologies
9 Technology (and biotechnology) applications

1 Survey

Extensive exploration of the region (including each of its sub-regions) is necessary to develop effective baseline data to plug the gaps in our existing knowledge of the region, such as regarding medicinal plants, lower groups of plants and animals, and 'hot spots'. Keystone, endangered, rare, and endemic species of the region need to be determined, based on the information related to identification, recognition and understanding of the distributional patterns, ecological preferences, age structure/maturity, community structure and composition, endemism, and disjunct distribution. Such research has to be on a continuing basis, with relevant methodologies for data collection being evolved from time to time, depending on the changing needs.

2 Composition, structure and function of ecosystems

Several long-term research programmes would have to be developed so as to improve our understanding of the following aspects of the Western Ghats ecosystems.

- Structure and dynamics
- External impacts/threats
- Biological response to change
- Interaction of species/inter-linkages between species
- Successional status of key species
- Ecological restoration of degraded micro/macro habitats
- Microbial community in soils
- Soil restoration.

The baseline data and information on these parameters would enable us to understand the dynamics involved in the functioning of ecosystems.

3 Monitoring

In order to observe ongoing changes in ecosystems, a mechanism of continuous monitoring is essential. The influence of biotic factors, and the pattern and distribution of biological diversity, are among the most important aspects to be included in a monitoring programme. This can be achieved through developing ecological models using GIS for both monitoring and forecasting. Environmental impact assessment of both ongoing and new development projects is also needed in order to assess the likely impact on biological diversity.

4 Sustainable use

In this area, a significant gap exists in our knowledge and understanding. For example, research on prospecting biological diversity and its evaluation for potential use is completely missing in our conservation programmes. There is need for developing cost-effective methods for evaluation and multiplication of biological resources of potential economic value. There is also need to evolve effective systems for bio-regional management, taking into account the size and shape of protected areas and the existing land-use patterns.

5 Valuation

Any effort towards conserving biological diversity in the Western Ghats would be meaningless if the development programmes do not take into consideration the real ecological, economic, social, and cultural value of these resources for the survival of the people living in the region. Therefore, it is essential that research activities should be initiated to provide appropriate valuation of the biological diversity in terms of ecosystem services, crop and animal genetic resources, option values, and existence value (Flint 1991). The existing environmental impact assessment may also need to be directed towards monetized and non-monetized

evaluation. These studies need to be supported by valuation of non-sustainable versus sustainable use, and subsistence use of biological resources. This kind of valuation will contribute to decision-making by demonstrating how biological diversity is undervalued by markets and the society.

6 Integration of traditional knowledge and skills

The integration of traditional practices is of vital importance if the goals of conservation and sustainable use of biological diversity are to be met. Therefore, traditional knowledge and skills must be blended with modern tools of conservation. Extensive ethno-biological surveys are necessary to assess the potential conservation value of traditional knowledge. On the basis of this knowledge, appropriate management strategies will also have to developed.

7 Social, economic, and cultural factors

The variety of modern scientific tools available cannot by themselves succeed in conserving biological diversity without an appropriate understanding of the complex and inter-related social, economic, and cultural factors affecting biological diversity. We will have to look into various issues such as effects of agricultural development, the implications of trade practices and intellectual property rights, and the impact of various development activities. We will also have to identify alternatives to ensure sustainable use of biological diversity. Methods will have to be evolved to generate value-added products from biological resources at the local level, and to provide incentives to local communities for conservation.

8 Developing restoration technologies

As a result of unscientific and non-sustainable exploitation of biological resources, certain areas in the Western Ghats region have become badly degraded. In order to restore them, studies are necessary, first, to document the physical and biological characteristics of these degraded areas and their causes of degradation, and, secondly, to determine appropriate land-use, including suitable species for restoration. Based on this, appropriate methods could be designed for restoration through pilot-scale projects, involving local people, and the progress of the projects could be evaluated. This will enable managers to concentrate their efforts on restoring the degraded areas, and on enriching them through the various options available to them.

9 Technology (and biotechnology) applications

The priorities outlined above will need to be supported through low-input biotechnologies for restoration and multiplication of economically important species, particularly for the degraded areas. High-input biotechnologies are re-

quired for both *ex situ* and *in situ* conservation of keystone, rare, endangered, and threatened species.

The conserving of biological diversity anywhere in the world is a long-term activity, which cannot produce immediate results. This is all the more so in the biologically and culturally complex Western Ghats region. However, the entire process requires sustained commitment in terms of human capacities, scientific researches, and policy measures related to water-harvesting, land-use, and exploitation of biological resources.

References

Anonymous. 1993
Policy Actions for Biological Diversity
Madras: M.S. Swaminathan Research Foundation. 62 pp. [Proceedings No. 5]

Ahmedullah M and Nayar M P. 1987
Endemic Plants of the Indian Region, Volume 1
Calcutta: Botanical Survey of India. 261 pp.

Daniels R J R. 1992
Geographical distribution pattern of amphibians in the Western Ghats, India.
Journal of Biogeography **19**: 521-529

Flint M. 1991
Biological diversity and developing countries: issues and options (a synthesis paper).
London: Overseas Development Administration. 50 pp.

Gadgil M. 1984
An approach to ecodevelopment of Western Ghats
The Administrator **29(4)**: 339-379

Developmental forestry in Karnataka and conservation of biodiversity

S Parameswarappa
Karnataka Forest Department
Aranya Bhawan, Bangalore - 560 003

The forests of India are extremely rich in biodiversity as they are spread over various climatic and altitudinal zones from sea level to the permanent snow-line in the Himalayas. These forests fall under 14 major forest types varying from tropical moist evergreen forests found in the north-eastern states and Andaman and Nicobar islands through dry deciduous scrub forest in the desert areas of Rajasthan to sub-Alpine forests in the Himalayas. This wide range of ecosystems provides a rich storehouse of nearly 65 000 known species of animals, plants, insects, fish, reptiles, and birds. Thus, forests form the most visible and viable part of our biodiversity resources and should be considered as the core sector for biodiversity preservation of the country.

Karnataka has a land area of 192 204 km^2 and a forest area of 38 000 km^2, spread between latitudes 11°31' and 18°0' North and longitudes 74°12' and 78°40' East. It has a coastal strip 10 to 50 km wide along the Arabian Sea, a mountain belt of the Western Ghats 30 to 50 km wide, rising to 2000 m, and a gently sloping plateau to the east. The rainfall, received mainly from the south-west monsoon between June and September, varies from 6000 mm in the west to 375 mm in the north-east, resulting in a diversity of vegetation types.

In the west and in the *ghats*, there are evergreen/semi-evergreen forests with giant trees rising to a height of 40 m. The main species are *Dipterocarpus indicus, Calophyllum tomentosum, Canarium strictum, Artocarpus hirsuta, Vateria indica, Mangifera indica*; a multitude of other species, in three to five discernible tiers, are also present. It is the home of ebony (*Diospyros ebenum*), white cedar (*Dysoxylum malabaricum*), pepper (*Piper nigrum*), cinnamon (*Cinnamomum zeylanicum*), and cardamom (*Elatteria cardamomum*). The geological structure, the exposed aspect, and the lashing rains have resulted in enclaves of grassland as climatic climax within these forests. These grassy banks have been expanding due to annual fires.

To the east of this zone are the moist deciduous forests, rising to 30 meters, with teak (*Tectona grandis*), rosewood (*Dalbergia latifolia*), india laurel (*Terminalia tomentosa*), *Pterocarpus marsupium, Lagerstroemia lanceolata, Albizzia* species, and bamboo (*Bambusa arundinacea*). These forests are of high economic value. The damage to the forests in this belt from grazing, fire, and collection of firewood is of average intensity. These forests are the home of elephant (*Elephas maximums*), tiger (*Panthera tigris*), panther (*Panthera pardus*), bison (*Bos gaurus*), sambar (*Cervus unicolor*), spotted deer (*Axis axis*), and other animals.

The next belt to the east, though degraded, comprises dry deciduous forests rising to 10 m with *Anogeissus latifolia, teak, Terminalia* species, *Hardwickia binata, Buchanania latifolia, Phyllanthus emblica*, sandal (*Santalum album*), and bamboo (*Dendrocalamus strictus*). The zone could be rich in wild life, with elephant, tiger, panther, wild pig (*Sus scrofa cristatus*) spotted deer, etc., where protected. It is also rich in economically important species, which yield non-wood forest produce. The open scrub forests further east and north, with *Albizia amara, Chloroxylon swietenia*, and thorny Acacias, spread over the driest zone, are in a very bad shape.

Karnataka's unique wetlands, rich in aquatic and bird life, providing food and shelter as also the breeding and spawning ground for marine and freshwater fish, face problems of pollution and over-exploitation. The major rivers of India also face problems of pollution and siltation. India's long coastline is under similar stress. Coastal vegetation including mangroves and sea grasses is getting denuded. The mountain ecosystems are under threat of serious degradation.

Coral reefs are the most productive marine ecosystems and provide habitat for diverse flora and fauna. These ecosystems are adversely affected by indiscriminate exploitation of coral for production of lime, recreational use, and for trade in ornaments. Similarly, the fragile environs of island ecosystems have been subjected to pressures of various forms including migration of people from the mainland.

The overriding impact of demographic pressures on India's resources and ecosystems, due to poverty and overpopulation (both human and livestock), needs to be highlighted. Unless there is a check on population growth and even a reduction of such populations and a corresponding improvement in land-use policies, the current trend of over-exploitation and ecological degradation is not likely to change. This will seriously affect biodiversity conservation.

Thus, we are faced with the need for accelerating the pace of development for alleviation of poverty, which is, to a great extent, responsible for many of our environmental problems. On the other hand, we have to avoid proceeding along the paths with environmental costs so high that these activities cannot be sustained. Development has to be sustainable and all-round, whether for the poor

or the not-so-poor, or for the village folk or townsmen.

The agenda for action in this regard will include the following.

- Ensure sustainable and equitable use of resources for meeting the basic needs of the present and future generations without causing damage to the environment.
- Prevent and control future deterioration of land, water, and air, which constitute our life-support systems.
- Take steps to restore ecologically degraded areas and for environmental improvement of rural and urban settlements.
- Prevent further damage to and conserve natural and man-made heritage.
- Ensure that the environment and productivity of coastal areas and marine ecosystems are protected.
- Conserve and nurture the biological diversity, gene pool, and other resources through environmentally sustainable development and management of ecosystems, with special emphasis on our montane, marine, coastal, desert, wetlands, riverine, and island ecosystems.
- Protect the scenic landscapes, areas of geomorphological significance, unique and representative biomass and ecosystems and wildlife habitats, heritage sites/structures, and areas of cultural importance.

Two million hectares of forests in Karnataka are in different stages of degradation.

Today the scenario in the forestry sector is most challenging. On the one hand there are mounting demands for timber and pulpwood to meet the burgeoning urban needs of the country and on the other hand there is tremendous pressure on the forests for land, firewood, and small timber for village communities. To compound the issue, environmental activism is gaining momentum in the country and we have moved to the other extreme, banning the felling of green trees in the forests.

Keeping this scenario in mind, the National Commission on Agriculture, in its report in 1976, laid stress on the following.

- Conservation forestry in ecologically sensitive and wildlife-rich areas.
- Production forestry in severely degraded and barren forest areas.
- Social forestry in non-forest land to make the rural communities self-sufficient in fuel, fodder, and small timber.

The 1980s saw an upsurge in investment in social forestry almost to the neglect of conservation of natural forests and production forestry. The state of Karnataka did take care of the conservation needs by stopping felling for

industrial needs and reducing the harvest levels in natural forests. Production (plantation) forestry is also being attempted, through forest corporations, on degraded areas through mechanized site preparation and planting. Plantation forestry continues to be both an economic and ecological imperative. Planting of barren lands, after mechanized site preparation, with fast-growing species is necessary to increase the productivity so that more wood is produced per unit area at less cost. It is only then that the pressure on natural forests is taken off and the little that is left of them could be saved along with the biodiversity they contain.

The state government, realizing all these issues, has initiated various developmental projects to generate alternative forest resources to meet the social demand.

Plantation forestry

Plantation forestry is nearly a century-old practice in Karnataka. It is estimated that nearly a million hectare of forests plantations has been raised by the forest department under various schemes and at present, nearly 50 000 ha of barren land and degraded forests are brought under green cover every year through departmental and farm forestry programmes.

In the beginning, under the plantation programme, afforestation was limited to planting teak in the moist deciduous and semi-evergreen belt. This was in small patches, raised in clear-felled and burnt areas. To begin with, the plantations were raised from seed and, since the 1930s, from stumps planted in holes made with crow-bars. Later, there was a marked change in planting technique as well as the number of species planted. Today, it is gratifying to mention that the Department of Forests has been able to develop standardized practices both for nursery and field for nearly 150 evergreen, semi-evergreen, moist, and dry deciduous species.

In the dry zone in the eastern plains of the state, the plantation programme began in the 1950s mainly as a soil conservation measure, without aiming much at biomass production. Later, due to acute shortage of biomass for both industry and rural communities, priority was accorded to raising fast-growing species in the wet zones of the state up to the 1980s. In their anxiety to produce more biomass in a short time, foresters chose exotics for large-scale plantations. However, by the mid-1980s, the emphasis was shifted to local species, some of which were as good as the exotics in biomass production.

Problems in forest protection

The problems faced by foresters in protecting and managing the forest wealth in Karnataka are innumerable. De-reservation of forests for farming, excessive exploitation to meet the industrial demand, fire, overgrazing due to increased

cattle population and decreased common lands, illegal felling, and increased demand for firewood, small timber, and construction timber for village communities are causing an irreparable damage to the forest wealth. Despite all these threats, thanks to the vigil and efforts of the forest department, we have some patches of valuable pristine forests that are yet intact, though rest of them are degraded due to heavy pressure.

Challenge to the foresters

Rural poverty and ecological degradation are interlinked. Today, many villagers who have no means of earning, and literate but unemployed youths, fall an easy prey to the temptation of stealing teak, rosewood, and sandal. With the shortage of wood and consequent increase in price, protecting forests from thieving is becoming more and more difficult. Despite many protective measures taken by the state government to check the rapid degradation of forests, the problem still persists due to various socio-economic factors. The mounting demand for fuelwood, fodder, and small timber from rural communities is the major concern of the state government and the forest department. Though, in the past, efforts were made to meet the local demands by raising plantations, it had not been possible to meet them fully, owing to paucity of funds. Even today, it is unfortunate that investment in forestry is less than 1% of the total outlay for a Five-Year Plan, at both the national and state level. At present, the forest department cannot meet even 10% of the total demand for firewood and timber despite so much plantation activity.

Table 1. Plantation details raised under various schemes since 1956.

Name of the species/ type of plantation	*Extent (ha)*
Teak	126 623
Soft wood	57 007
Cashew	39 373
Eucalyptus	130 938
Firewood	514 013
Bamboo	6 138
Lavender	1 097
Cocoa	1 595
Rubber	6 043
Sandal	4 205
Usufructs	1 736
School gardens	5 946
Roadside plantations	11 276
Canal banks	2 393
TOTAL	908 383

Social forestry project

With this background, the state government took up social forestry projects in the state from 1983/84 with financial assistance from the World Bank and the Overseas Development Administration (UK), mainly to help the rural community to meet its day-to-day needs of firewood, fodder, and small timber from social forestry plantations raised on common lands, community lands, and farm lands.

Cultural diversity and biodiversity are essential for both man and nature. Biodiversity can be achieved by both *in situ* and *ex situ* conservation measures. *In situ* conservation is both effective and inexpensive. For a developing country such as India, *in situ* conservation measures are more appropriate but these can be achieved only by taking the pressure off sensitive areas rich in biodiversity. All such efforts are by way of strategies for conserving biodiversity in the state.

Summary of principal conclusions and suggestions for action: forest ecosystems

Kartar Singh
British Council Division, British Deputy High Commission
737 Anna Salai, Madras - 600 002

Introduction

1 The case-study material afforded by the brief study tour in a part of the Western Ghats, supported by the additional information provided in the Bangalore Workshop, was used in the discussions to derive such issues and principles as are considered to be widely important within the Western Ghats region and, in many cases, elsewhere in India. In view of the huge gaps in knowledge regarding the composition of biodiversity and functioning of these complex ecosystems, scientific co-operation, including assistance with education and training to increase the capability of scientific manpower within India, was seen as an appropriate area for Indo-British collaboration.

2 While concentrating particularly on scientific and technical collaboration, the participants recognized at the outset that the success of any such programme would be dependent on the establishment of appropriate policy and institutional environment, both within India and internationally. For example, international trade practices may have a major influence on the viability of forest conservation and reforestation programmes in tropical countries. Similarly, within India, the cross-sectoral impacts within overall development policies and the role of forests in the conservation of soil and water resources, and their contributions to stabilizing regional and global climate, cannot be divorced from policies and planning for conservation of biodiversity. However, given the specific focus of the Workshop, and the very limited time available for discussions, such areas of broad policy and institutional issues were not discussed in detail.

3 The Workshop also recognized the importance of effective linkages between research and application, and the vital role of teachers and extension organizations in the transfer of knowledge and understanding on biodiversity conservation to local people. In the interests of brevity, this summary report does not attempt to spell out such aspects in detail. Nor does it attempt to list all

the possible specialist fields of scientific expertise that may be involved. However, more details are provided in some of the papers presented at the Bangalore meeting.

Principal conclusions

4 The Western Ghats are one of the richest biodiversity areas in India, and are of major regional and international significance in this regard.

5 The natural forests are already heavily reduced in size, and fragmented. Urgent action is needed to halt further erosion of biodiversity and to secure its conservation and sustainable use through efficient management of forests and the biodiversity they encompass. Particular care should be given to the possibly adverse impacts on the natural forest communities of introducing invasive exotic species.

6 There are major threats to many taxa of both flora and fauna, and to the satisfactory functioning of the ecosystems, from the pressures on forest resources and injudicious use of land. These are the result of high human and cattle populations, aggravated by their uncontrolled growth, and by the effects of poverty and unemployment. There are also adverse impacts from indiscriminate development activities and tourism.

7 In the face of these extreme biotic pressures, the conservation of biodiversity is essentially dependent on increasing the sustainable supply of the products (especially fuelwood, fodder, etc.) now being taken from the forests, and/or reducing the levels and rate of increase in human and livestock populations. The increased production should come from the rehabilitation and reforestation of degraded lands and farmlands within the framework of rational land-use plans. High priority should also be given to the ecological restoration of severely degraded natural forests.

8 Public education and extension activities to create awareness of the need to conserve biodiversity should accompany the intensified production programmes.

9 Conservation of the forest ecosystems is essential to conserve the biodiversity of the Western Ghats.

Suggestions for action

10 Assembly, review, compilation, and synthesis of relevant existing data and information relating to biodiversity in the Western Ghats.

11 Creation of a comprehensive database on biodiversity of the Western Ghats, including data on species attributes, distribution, and potential uses (with particular attention to medicinal plants) and on their interrelationships in the functioning of the ecosystem.

12 Integration of traditional knowledge and skills into the database and into the field programmes for the conservation and sustainable use of biodiversity.

13 Planning and execution of surveys and inventories aimed to characterize and quantify the biodiversity in selected areas, and to develop efficient methodologies for the survey and monitoring of biodiversity throughout the Western Ghats. Such surveys should give high priority to identification and inventory of species with high socio-economic values.

14 Review of the existing network of totally protected areas (national parks, wildlife sanctuaries, etc.) and selection and prioritization of additional areas to be included in the network.

15 Identification of 'hot spots' in terms of their high biodiversity value and high degree of current or threatened damage owing to biotic pressures, followed by urgent remedial action, assisted as necessary by research, to develop efficient methodologies for ecological restoration.

16 Research into the functioning of forest ecosystems, with particular attention to the role of lower groups of plants, invertebrates (especially insects), and fungi and other microorganisms.

17 Research into the relationship between the carrying capacity of and the nature and intensity of disturbance to the forest ecosystem and species-richness to assist in the introduction of ecologically sustainable forest management and harvesting systems in appropriate areas.

18 Studies of the socio-economic and cultural factors affecting the conservation or loss of biodiversity, and the identification of appropriate incentives and disincentives to secure the support of local people and communities, including improved opportunities to derive greater benefits through value-adding processes.

19 Development of an efficient planning framework at both the grassroots (micro-planning) and higher levels, within the context of regional, state, and national strategies for biodiversity conservation.

20 Studies into the socio-economic valuation of biodiversity to assist in the proper assignment of priority and resources to the conservation of biodiversity in overall development plans at both the national and subsidiary levels.

21 Development of information networks, research networks, and bio-resource centres to assist in efficient co-ordination of action and the development of organic linkages between the institutions and organizations (both governmental and non-governmental) involved at the local and regional levels.

22 Strengthening of the role and capacity ICFRE (Indian Council of Forestry Research and Education) to serve as a national centre for research and information on the conservation of forest biodiversity.

23 Development of appropriate technologies and capabilities for *ex situ* conservation of forest genetic resources to safeguard valuable populations and

genetic material that cannot be adequately and securely conserved *in situ*.

24 Establishment of comprehensive reference collections, properly representative of the biodiversity of the Western Ghats, on the basis of exploration programmes, planned to take account of existing collections, and of information on patterns of distribution and/or environmental variation, giving priority to the filling of major gaps in important groups of organisms.

25 Development of GIS (geographical information systems) to assist in the efficient collection, storage, analysis, interpretation, and display of information on biodiversity, and its ready accessibility for use at both the strategic planning (and monitoring) and the field operational levels.

26 Action to increase the availability of scientific and technical manpower in appropriate fields by the intensification of training programmes, innovative approaches such as the recruitment and training of 'parataxonomists', and the mobilization of skilled manpower available from both national and overseas institutions, particularly with regard to insects and fungi.

27 Definition and prioritization of the needs for international technical and financial assistance, with particular attention to the need for scientific collaboration in fields such as biosystematics, ecology, autecology, ecophysiology, functional morphology, population biology, etc.

28 Active participation in the proposed Commonwealth Initiative to develop an international network of selected areas for the demonstration and development of forest management systems, designed to link the conservation of biodiversity with productive use of forests.

29 Appropriate use of advanced technologies for the propagation and conservation of endangered species and populations, particularly with regard to endemics, and the development and transfer of biotechnology in the field of biodiversity conservation.

Wetlands

Initiatives for conservation of wetlands in India

Dilip K Biswas and *C L Trisal*
Ministry of Environment and Forests, Paryavaran Bhawan
C G O Complex, Lodhi Road, New Delhi - 110 003

Wetlands in India

Wetlands in India are distributed in various regions ranging from the cold arid zone of Ladakh through the wet Imphal in Manipur and the warm and arid zone of Rajasthan–Gujarat to the tropical monsoonic central India and the wet humid zone of the southern peninsula. To inventorize the wetlands in the country, the Ministry of Environment and Forests carried out a survey in 1990. According to this survey, about 4.1 million hectares are covered by wetlands of different categories (Table 1). In addition, mangroves – the coastal wetlands – occupy an area of about 6740 km^2, about 80% of which is in the Andaman and Nicobar Islands. Stretches of mangrove vegetation are also found in coastal Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Gujarat, and Goa.

Categories of wetlands

Wetlands in India can be broadly classified into the following categories: (1) Himalayan wetlands, (2) Indo-Gangetic wetlands, and (3) coastal wetlands.

Himalayan wetlands

The Himalayan region has been bestowed with a number of wetlands showing remarkable variation in their nature and biota. The Himalayan region can be divided into three sub-regions: (1) Western Himalayas, (2) Central Himalayas, and (3) Eastern Himalayas.

In the Western Himalayas, the Ladakh and Kanskar region (4000 metres above the mean sea level) harbours a large number of high-altitude wetlands. These biotopes are exposed to cold desert conditions with high solar radiation during a short summer period. Both saline and freshwater wetlands are encountered in this region. The important ones are Pangong, Tso, Tso Morari, Chantau, Noorichan, Chassul, and Honlay.

Table 1. Distribution of wetlands in India, including wetlands of less than 100 ha, by state/union territory

State	Number	Natural Area (ha)	Number	Man-made area (ha)
Andhra Pradesh	219	10 0457	19 020	425 892
Arunachal Pradesh	2	20 200	NA	NA
Assam	1 394	86 355	NA	NA
Bihar	62	224 788	33	48 607
Goa	3	12 360	NA	NA
Gujarat	22	394 627	57	129 660
Haryana	14	2 691	4	1 079
Himachal Pradesh	5	702	3	19 165
Jammu & Kashmir	18	7 227	NA	21 880
Karnataka	10	3 320	22 758	539 195
Kerala	32	24 329	2 121	210 579
Madhya Pradesh	8	324	53	187 818
Maharashtra	49	21 675	1 004	279 025
Manipur	5	26 600	NA	NA
Meghalaya	2	NA	NA	NA
Nagaland	2	210	NA	NA
Orissa	20	137 022	36	148 454
Punjab	33	17 085	6	5391
Rajasthan	9	14 027	85	100 217
Sikkim	42	1 101	2	3.5
Tamil Nadu	31	58 868	20 030	201 132
Tripura	3	575	1	4 833
Uttar Pradesh	125	12 832	28	212 470
West Bengal	54	291 963	9	52 564
TOTAL	2 164	1 449 338	65 250	2 587 965
Union territories				
Chandigarh	NA	NA	1	170
Pondicherry	3	1533	2	1 131
GRAND TOTAL	2 167	1 450 861	65 253	2 589 266

Wetlands situated in the Kashmir Valley include the Dal, Anchar, Wular, Haigam, Malgam, Haukersar, and Kranchu. These lakes have been extensively studied.

In Himachal Pradesh, several natural lakes occur in tropical, subtropical, temperate, and alpine climatic regions with altitudinal variations ranging from 400 m to 5000 m above the mean sea level. Major high-altitude (2500 m to 5000 m) lakes include Nako, Cander Natan, Chandertal, and Surajtal. In the mid-altitudinal zone (1500 m to 2500 m), the prominent lakes include Khajiar, Kareri,

Kumarwah, and Rewalsar. In the low altitudinal zone (up to 1500 m), Renuka and Saketi are the important lakes and they experience subtropical climatic conditions.

The wetlands situated in the Central Himalayas are mostly located in the Kumaon region. Nainital, Bhimtal, Naukuchital, and a number of other small lakes are situated within this region. These lakes are surrounded by hills, which slope steeply to the water bodies and receive significant loadings in the form of water and organic matter from the catchment areas. Some parts of these lakes along the shores have become shallow as a result of siltation from the catchment areas.

In the Eastern Himalayas, large number of wetlands are situated in Sikkim, Assam, Arunachal Pradesh, Meghalaya, Nagaland, and Manipur. These wetlands together with sanctuaries of the Brahmaputra valley are internationally important for a number of bird species such as *Ardea imperialis, Leptoptilosdubius, Francollis qularis, Perdicula manipurensis manipurensis, Grus nigricollis, Houbaropsis bengalensis, Saxicola jerdoni, Pellorneum palustre, Moupinia altirostris, Prinia burnesi,* and *Ploceus meoarhynchus*. Besides, these wetlands also harbour rhinoceroses, tigers, marsh deer, elephants, crocodiles, and water buffaloes. The Loktak lake, with an area of 289 km^2, is one of the largest freshwater lakes situated in this region. The floating swamps of Keibul Lamjao adjacent to Loktak provide refuge to the Manipur brow-antlered deer, *Cervus eldi*, which is an endangered species.

Indo-Gangetic wetlands

Most of the wetlands in India are directly or indirectly associated with river systems such as the Ganges, Brahmaputra, Narmada, Tapi, Godavari, Krishna, and Cauvery. The largest wetlands region of India is the Indo-Gangetic flood plain. The alluvial plains of the Ganges comprise a vast crescent-shaped lowland about 250 to 300 km wide between the Deccan peninsula and the Himalayas. The wetlands of the Gangetic plain and the Himalayan *Terai* provide winter refuge for millions of waterfowl, particularly in the states of Uttar Pradesh and Bihar. Wetlands are scattered all along the course of the river Ganges and its tributaries. Prominent among them are the East Calcutta wetlands in West Bengal, Chaurs of Bihar, the flood plains of Uttar Pradesh, Chambal wetlands in Madhya Pradesh, and Keoladeo Ghana National Park in Rajasthan. Various multi-purpose projects launched to harness these river systems have also created a number of man-made wetlands, e.g. Harike Barrage at the confluence of Beas and Sutlej in Punjab, Bhakra Nangal Dam in Punjab and Himachal Pradesh, and the Kosi barrage at the Nepal border.

Coastal wetlands

India has a long coastline of over 7500 km. All along the coastline, wetlands are situated, dominated by mangroves, salt marshes, lagoons, etc. Pulicat lake, Periyar lake, Chilka lake, Kolleru lake, etc. are situated within this area.

There are relatively few natural wetlands in the Deccan, the southern-most section of the Indian peninsula. However, there are innumerable small reservoirs or tanks, which have been constructed near virtually every village. These tanks provide important feeding and nesting areas for a wide variety of water birds.

The peninsulas of Saurashtra and Kachchh separated from the main peninsula by the Gulf of Khambhat, along with neighbouring Rajasthan and Madhya Pradesh, are of great importance from a wildlife and ecological point of view.

Threats to wetlands

The wetlands face various forms of environmental problems. These are due not so much to the natural processes as to encroachment and incursions of human activities.

Encroachment

Large number of people living in and around wetlands have been encroaching upon these areas and vast areas have already been drained for agriculture, urban expansion, and other purposes.

Siltation

Siltation is one of the major problems in most of the wetlands in India. Deforestation and other anthropogenic activities have accelerated soil erosion, causing increased sedimentation rates and the resultant shrinkage of wetlands. About 13 million tonnes of silt is deposited annually in Chilka lake, choking its mouth, leading to reduced communication with the Bay of Bengal. Some other lakes that face this problem include Wular, Dal, Kolleru, and Loktak.

Weed infestation

Almost all wetlands in the country, barring a few located in the high altitude Himalayas, are heavily infested with aquatic weeds. *Eichhornia crassipes*, *Ipomea* spp., *Salvinia natans*, *S. molesta*, *Paspalum* sp., etc. pose a great threat to the wetlands, hampering their ecological functions.

Pollution

A large number of wetlands in the country are subjected to inflows of domestic sewage, solid waste, and other industrial effluents. Fertilizer and pesticide run-off

from agricultural lands also aggravate the pollution load. All these factors are responsible for accelerating the process of eutrophication (algal bloom).

Aquaculture

Use of wetland areas indiscriminately for aquaculture is also a major threat to the well-being of wetlands.

The symptoms of strain due to the cumulative effect of the above pressures are becoming increasingly evident in the form of

- decrease in biological diversity, particularly endemic and endangered species
- deterioration of water quality
- sedimentation and shrinkage in the area
- decrease in migratory bird population, fish, and other faunal productivity
- prolific growth of obnoxious aquatic weeds.

Conservation initiatives

In the recent years, the Ministry of Environment and Forests has taken several important steps for the conservation of wetlands, mangrove, and coral reef habitats in the country. A National Committee on Wetlands, Mangroves and Coral Reefs has been constituted to advise the Government on policies and programmes for the conservation of these ecosystems, to suggest specific sites for conservation action, and to identify research and training priorities.

State-level steering committees, headed, in most cases, by the Chief Secretary of the concerned state, have been set up to formulate, implement, and monitor the programmes. District-level committees have been also constituted for co-ordination and monitoring of programme activities at the field level. The Ministry of Environment and Forests provides full financial assistance to the state governments for carrying out activities related to the conservation and management of wetlands, mangroves, and coral reefs identified for such purposes.

National Wetlands Programme

The two major components of this programme are preparation of management action plans and research activities.

Management action plans

Of the 16 wetlands identified (Table 2) by the National Committee, management action plans for 10 sites have been prepared, based on the problems identified in these wetlands.

Table 2. Wetlands under the National Wetland Programme

Wetland	*State/Union Territory*
Rollers	Andhra Pradesh
Wular	Jammu and Kashmir
Chilka	Orissa
Laktak	Manipur
Bhoj	Madhya Pradesh
Sambhar	Rajasthan
Pichola	Rajasthan
Ashtamudi	Kerala
Harike	Punjab
Ujni	Maharashtra
Sukhana	Chandigarh
Sasthamkotta	Kerala
Renuka	Himachal Pradesh
Kabar	Bihar
Nalsarovar	Gujarat
Kanjli	Punjab

The action plans consist of the following.

Protection. (1) Bringing the identified wetlands under the country' s protected area network of national parks, sanctuaries, and biosphere reserves. (2) Strengthening the infrastructure facilities of protected wetlands.

Siltation control. Soil conservation and erosion control through afforestation, vegetation contour bunding, construction of water-harvesting structures, gully control, and stream bank erosion control.

Pollution control. (1) Monitoring water quality of major, medium, and minor river systems, groundwater, and lakes by the central and state pollution control boards and under GEMS (global environmental monitoring system). (2) The MINAR (monitoring of Indian national aquatic resources) and the GAP (Ganga action plan) programmes. (3) Conducting environmental impact assessments of developmental projects affecting the wetlands. (4) Issuing administrative notifications such as the CRZ (coastal regulation zone) notification imposing graded restrictions on industrial operation and processes in coastal areas, and banning construction within 500 m of the high-tide line of ecologically sensitive areas.

Weed control. (1) Biological control (on an experimental basis) and manual removal of aquatic weeds. (2) Evolving a comprehensive, integrated, and long-term approach to combat the weed menace.

Afforestation. Afforestation in the catchment areas of Bhoj (Madhya Pradesh), Wular (Jammu and Kashmir), Harike and Kanjli (Punjab), and Chilka (Orissa).

Wildlife conservation. (1) Captive breeding of some endangered, wetland-dependent wildlife species such as rhinoceros in Assam, *sangali* in Manipur, and freshwater turtles. (2) Improving wetland habitats for waterfowl.

Fisheries development. Emphasizing sustainable utilization of fishery resources rather than short-term gains through intensive aquaculture of natural wetlands.

Legal aspects. Enacting of legislations such as the Environment (Protection) Act, 1986; Water (Prevention and Control of Pollution) Act, 1974; Forest (Conservation) Act, 1980; and Wildlife (Protection) Act, 1972.

Environmental education. (1) Building awareness about the values and the need for conservation of wetlands among all target groups through audio-visuals, posters, nature camps, films, etc. (2) Conducting the national environmental awareness campaign every year.

Keeping in view the problems confronting the wetlands in India and the research studies carried out so far, the following priority areas have been identified under the wetlands programme.

- Survey and mapping of wetland resources in the country using remote sensing technology.
- Application of GIS and mathematical modelling in some selected wetlands.
- Evolving wetland evaluation techniques to facilitate quick appraisal of the health of specific wetland ecosystems and also environmental impacts of developmental projects and other human activities in the ecosystem.
- Control of prolific growth of some exotic species.
- Siltation control.
- Fisheries development.

Recently, the Ministry of Environment and Forests has helped in setting up the Salim Ali Centre for Ornithology and Natural History at Coimbatore for conducting basic and applied research, and for creating a databank on Indian ornithology. The investigations conducted by the Botanical Survey of India and the Zoological Survey of India, along with several projects supported by the Ministry under the wetlands programme, have yielded useful scientific information as required for sustainable management of the wetlands.

Wetland research and survey priorities in the British Isles and their relevance to India

C Newbold
Joint Nature Conservation Committee
Monkstone House, City Road, Peterborough, Great Britain PE1 1JY

Abstract

The research and survey priorities for wetlands in the British Isles and India, despite differences in their climates have some similarities. Systematic survey and categorization of India's wetlands, and describing and typing them according to their nature and extent, is however suggested as the first priority. The methodology used in Britain, which ranks wetlands on a regional, national, and international basis, is discussed.

Lists of major wetland research projects carried out in Britain are given. Five themes are selected. Comparisons are made with sites in India. The themes are hydrology, nutrient budgets, sediment loading, catchment management plans, and socio-economic studies. Comparisons are made between studies in Britain and those of Chilka lake and Bhitarkanika in Orissa, India.

Introduction

Many of the research problems that relate to the conservation of the biodiversity of any wetland type are as relevant in the tropical zones as they are in temperate climates. Research in the British Isles is mainly focused around three aims. The first two are the maintenance or enhancement of water quality and water quantity. Embraced in these two aims is the third aim, which is the management of systems to maintain or enhance biodiversity. These aims are equally applicable in India.

One other strategy in Britain is to establish through survey the nature and extent of wetlands, and to categorize and describe them according to established criteria. The philosophy behind the typing and description of key wetland areas in the British Isles is found in the *Nature Conservation Review* (Ratcliffe 1977). The extent of most of the major wetlands in India is categorized (MOEF 1992, Ghosh 1989) but descriptions of their nature or *in situ* biodiversity, and grouping into different wetland types, seem to be still lacking.

This paper concentrates on five themes: (1) the approach adopted within the British Isles to categorize the wetlands, describing their nature and extent; (2) the relevance of hydrological research describing and maintaining water quantity; (3) the importance of nutrient and sediment budgets in assessing and partitioning those components of the catchment that affect water quality; (4) the planning and integrated management of the catchment necessary to conserve wetland biodiversity; and (5) the importance of socio-economic research and the use of the wetland resources compatible with maintaining or enhancing biodiversity—the sustainable use of a wetland.

Survey priorities in the British Isles

The survey priority for wetlands has been to categorize the range and extent of all major wetland ecosystems. These are defined as standing and running waters, fens, valley mires and upland mires, coastal systems, and estuaries.

The criteria for assessment are based on the philosophy within the *Nature Conservation Review* (Ratcliffe 1977). The criteria are size, diversity including habitats and species diversity, naturalness, rarity of both species and habitats, fragility, typicalness, uniqueness, systems that might encompass more than one ecosystem type, recorded history, position in an ecological/geographical unit, potential value, and intrinsic appeal (landscape value). One further wetland criterion has been added, namely its position in the catchment.

As well as the philosophy contained within volume 1 of *Nature Conservation Review*, there is a description of the range of plants and animals typical of each wetland type. Physical and chemical attributes, and geological, hydrological, and limnological characteristics, are also included (Table 1).

Table 1. Survey priorities in the British Isles (wildlife and physico-chemical components used to assess the status of wetland sites and assessment criteria)
(*After* Ratcliffe 1977)

Wildlife components	*Physico-chemical components*	*Assessment criteria*
Birds	Depth (if lake)	Size
Mammals	Water chemistry (including hardness)	Diversity (habitat and species)
Macrophytes or wetland plants	Sediment type	Naturalness
	Geology	Rarity
Algae	Hydrology	Fragility
Invertebrates	Salinity gradient in brackish systems	Typicalness
Amphibia	Macrotope (if mire system)	Position in ecological/ geographical unit
Reptiles	Hydromorphology (if mire system)	
Fish	Mesotope (mire margin, mire expanse)	Potential value
	Microtope (surface patterns of mires)	Intrinsic appeal (landscape value)
	Microforms (in mire systems)	Position in catchment

Volume 2 contains an inventory with site descriptions of the most diverse wetland sites found in the United Kingdom.

The value given to sites is assessed using the above criteria. Those having the expected range of near-natural plant and animal communities for a wetland type or, expressed another way, the maximum potential natural biodiversity, are given a potential natural nature reserve status. Others may have a higher status, being of international importance. These sites may have plant and animal communities important in a European assessment for the distribution of such species, or they may be internationally important roosting, overwintering. or breeding areas for wetland birds. Many sites, however, do not meet these high standards of national or international designation and are given regional or county status. These sites are still important in conserving the nation's *in situ* biodiversity. All sites – county or regional, national, and international – form a national series. All are protected under the Wildlife and Countryside Act (1981). In total, approximately 11% of Great Britain is conserved in this near-natural state. Approximately 2% is of national the nature reserve status.

It is suggested that an ordered typing and inventory of wetlands is needed for India, with an assessment of their value in regional, national, and international terms. Similar criteria could be used to that of the *Nature Conservation Review.* Characteristic plants and animals could be established from available data, thereby describing particular wetland types. Each site should have its own description.

This process seems particularly pertinent to arrive at the conservation value of a site through a comparative scientific process. Some sites may be undervalued if site evaluation is independent of their place in the national or international series.

Bhitarkanika, Orissa

This important area is of national importance but it could well be of international importance. The mangroves of Bhitarkanika are known to have unique communities of plants and animals. It has the largest number of mangrove plants, 62 species out of the known 64 species, encompassing the known distribution of species within the Sunderbans, the western coast of India, and the Andaman and Nicobar Islands (P Das, unpublished data). Comparative scientific assessment of mangroves within India therefore suggests that it should be accorded international status since there must be few sites in the world with such a complete community of mangrove species. A more scientific appraisal, after reviewing available literature, is necessary to establish its true status.

Research priorities in the British Isles

The main wetland research priorities which help to maintain *in situ* biodiversity in the British Isles are listed in Appendices 1, 2, and 3. Some aspects of these research priorities are considered in detail below.

Hydrological research

Understanding the hydrology of a wetland is often essential before management decisions are made. Calthorpe Broad, National Nature Reserve (in Norfolk, East Anglia) is a peat-lined mere, lying, it is known, on a shallow saucer of calcium-rich boulder clay. Hydrological research would have shown that the mere lay on a perched or elevated water table compared with the surrounding agriculturally altered peat fens. The saucer of clay only 1.0 metre thick and 1.0 metre below the surface extended out into these fens. A deeper drainage channel was dug in 1971 on the boundary of the reserve. The grazing fen land was turned into arable but, more importantly, the drainage ditch was deepened from the existing depth of 0.9 metre to 2.5 metres. This breached the clay saucer, breaking the perched water table. The water table in the drainage ditch now determined the water table in Calthorpe Broad. It fluctuated with the seasons, being regularly drawn-down in the summer and at peak levels in the winter. The sulphide-rich peat lining the mere was in a reduced state during high water and in an oxidized state during exposure to air and sunlight when the mere was drawn-down. This caused violent oscillations in pH from 7.0 to 3.2. During reduction processes, when the water levels rose, ferric sulphate was reduced to ferrous sulphate. Iron was released, causing the water to turn brown, but more importantly the sulphate ion combined with water to form sulphuric acid (Gosling 1971, Gosling and Baker 1980). To neutralize this acidity, several tonnes of limestone are added to Calthorpe Broad annually.

Deepened drainage ditches close to the coast in East Anglia have also caused saline intrusion into previously freshwater systems. A diverse invertebrate fauna was reduced to the most pollution tolerant genera such at *Tubifera* sp., *Simulium* sp., and *Stratiomys* sp.—all dipterous larvae (Driscoll 1983).

In northern Greece, the brackish water Middle lagoon, part or a Ramsar site, near Kavalla, was turned into a sterile hypersaline lagoon because the hydrology was not researched. Irrigation demands for freshwater reduced summer inflows so much that the freshwater/salinity gradient disappeared, being replaced by sea water. Summer evaporation renders the lagoon hypersaline. In winter, freshwater flows create a salinity gradient. Extreme fluctuations in salinity between winter and summer have a more marked effect on the flora compared with the former relatively stable salinity gradient. Aquatic floras, both marine and freshwater, have difficulty acclimatizing to such extremes. *Lemna trisulca* in stable salinities can tolerate up to 4000 ppm salinity as chloride but in an oscillating salinity, it disappears at salinities greater than 1000 ppm as chloride (Remane and Schlieper 1971).

Similarly, *Nuphar lutea* has an upper tolerance limit in stable salinities of 1400 ppm salinity as chloride but it disappears in oscillating salinities at 500 ppm. The

values for *Potamogeton natans* are 1100 ppm and 250 ppm respectively; for *Elodea canadensis,* they are 1400 ppm and 400 ppm respectively.

Chilka lake, Orissa

Understanding the hydrology and salinity gradient of Chilka lake is recognized by the Chilka Area Development Authority as an essential component in the long-term survival of the fisheries industry and the lake's biodiversity including the overwintering wildfowl (C R Das, personal communication). Flocks of 800 000 birds in winter are one reason for its Ramsar status. Of particular concern is the partially blocked outflow point to the sea, whether and where a new opening should be dug.

Nutrient budgets

Eutrophication or artificial enrichment is one of the most pervasive forms of pollution affecting many shallow and deep water lake systems (Lund 1972, Moss 1983). The most common reason for eutrophication is the controlled and uncontrolled, treated and untreated, discharge of urban sewage. More frequently nowadays, discharges from intensive animal husbandry units for cattle, pigs, and poultry also cause eutrophication. This intensification of animal production is more a feature of European agriculture. Britain, as a consequence of its relatively high population density, large urban centres, and intensive agriculture, has many wetlands suffering mild to serious eutrophication. This either causes a marked increase in production and biomass of one or more macrophytes, notably *Potamogeton pectinatus, Myriophyllum spicatum,* or *Elodea canadensis,* to out-compete other macrophytes. In extreme cases, it causes marked increases in algal production and biomass. These cause algal turbidity, affecting the light regime, and/or growths of epiphytic diatoms, which coat the leaves of macrophytes (Phillips, Eminson, Moss 1978). With mild eutrophication, only the most pollution tolerant macrophytes survive. In general, extreme eutrophication or enrichment causes a marked loss in biodiversity, with the total loss of macrophytes.

To explain and quantify the above processes, nutrient budgets have been constructed in lakes with commercial fisheries and nature conservation value. Studies have been carried out on Lough Neagh, Northern Ireland, (Gibson *et al.* 1971); Esthwaite Water, Cumbria; the Norfolk Broads, East Anglia (Moss 1983, Phillips 1984); and Loch Leven, Kinross, Scotland (Bailey Watts *et al.* 1987).

Phosphorus and nitrogen are key elements causing eutrophication but most nutrient budgets have tended to concentrate on explaining the phosphorus cycle. This is because phosphorus inputs often arise from point sources and are more easily quantified whereas nitrogen runs off from agricultural land as a diffuse source. Also, ten to twenty times less phosphorus has to be removed through

specialized treatment processes to effect the same reduction in plant production when compared to nitrogen. The nitrogen to phosphorus ratio is 10:1–20:1 for sustained plant growth.

Nutrient budgets, when properly researched, partition the various inputs from phosphorus relative to catchment use. A nutrient budget is given for Loch Leven, Kinross, Scotland (Table 2).

Table 2. Loch Leven phosphorus loading (*After* Bailey Watts *et al.* 1987)

Inputs	*% of total in 1967*	*Kg/week in 1967*	*% of total in 1978*	*Kg/week 1978*
Industry	53	151	4	8.5
Run-off from agriculture	25	74	52	112
Sewage	14	40	31	66.5
Atmosphere	7	20	13	28
TOTAL	100	285	100	215

In 1967, the greatest proportion of the phosphorus input came from a factory manufacturing woolen blankets. During the 1970s, the factory process was changed resulting in less phosphorus. In 1993, Loch Leven, a national nature reserve, was still enriched and a phosphorus stripping plant was incorporated into the sewage treatment process. Similarly, efforts were being made to target the agricultural sources of phosphorus, the main components being effluent from overwintering animal units and animal slurry applications to fertilize the farmland.

During 1980/81, the nitrogen inputs were studied and Cuttle (1982) indicated that agricultural sources were as high as 80% of the total loading entering Loch Leven. Levels of nitrate-nitrogen occasionally reached 10 mg/litre. Additionally, catchment area maps were produced, partitioning the catchment into sub-sectors identifying nitrogen and phosphorus loading figures and land-use in each. Similar studies have been carried out for Hickling Broad, National Nature Reserve (Moss and Leah 1982) and the river Bure, Barton Broad system in Norfolk, England (Phillips 1984).

Sediment loading

Another area of concern in the eutrophication process has often been the high sediment loading. This has been accreting, for example, in Barton Broad, Norfolk, England, at a rate of 6 mm/year. The expected sedimentation rate is approximately 1 mm/year (Phillips 1984). This high figure is attributed to two

sources, organic matter from five upstream sewage works and soil erosion due to under-drainage of the agricultural land. Soil erosion was particularly high following conversion of grazing land into arable. Generally, soil erosion and sediment loads are only researched if a major change in catchment use is known or likely to occur. In the uplands of Britain, newly afforested areas cause major soil erosion events (Newbold and Withrington 1989, Soutar 1989).

Chilka lake, Orissa

In recent years, sediment accumulation in the major inflow area to the lake seems to have been increasing. This sediment coupled with the available nutrients has resulted in the growth of extensive beds of *Potamogeton crispus* and *P. pectinatus*. Such increases in plant growth indicate that the lake is exhibiting the first signs of cultural eutrophication. Excess nutrients and sediments arise from catchment area use. The catchment area is mainly agricultural with some afforested land. Physically, the catchment area has very broad, flat, valley bottoms and is flanked by low hills forming part of the Eastern Ghats.

Sewage sources are numerous but the population density appears to be relatively low, with no major urban centres. The lake is also large (1165 km^2) relative to catchment area.

Nutrient retention time must be very high with an almost occluded exit to the sea. Also, the level of phosphorus to nitrogen would be naturally high due to the brackish conditions. Sea water has a higher phosphorus-to-nitrogen ratio than freshwater (approximately 1 part of phosphorus to 5 parts of nitrogen, compared to 1 part of phosphorus to 10–20 parts of nitrogen in freshwater).

Sediment and nutrient budget for Chilka lake, Orissa

Chilka lake would be better understood if a sediment and nutrient budget could be constructed. Essential to a sediment and nutrient budget is a study of each major component of catchment area use and its quantified contribution to the overall budget. Additionally, the relative importance of particular segments of the catchment area should be identified. This would prioritize and target areas for remedial action.

Of particular concern would be the following.

Sediment accretion. Sediment loads are of particular concern to the Chilka Area Development Authority. Sediment traps have been constructed close to the inflow. The main concern seems to be the rapid delta formation at the inflow and the increasing cover of *P. crispus* and *P. pectinatus* beds. This in turn reflects concern by the Authority over a reduced area for fishing rather than an equally important concern of the impedance to flows caused by sediments and its effect on increasing retention times.

There are two further concerns:

- Freshwater inputs caused by the partially blocked outflow point to the sea can, potentially, have certain effects on retention times.
- Sediment loads are an indication of soil erosion and the cause is best targeted. Simple bunds constructed on a field basis over the agricultural catchment, particularly in the upper catchment, could contain most of the monsoon flows but, more importantly, they could contain sediments. What is being proposed is a system of modified field terracing. It is only the cumulative effect of flows from each field that causes an uncontrolled flood. Simple as this suggestion is, it implies a commitment from each land owner and calculations made of the appropriate height of each bund dependent on its position in the catchment. There would have to be an organized release of contained field water after the monsoon from sluices set in each bund.

Potamogeton crispus *and* P. pectinatus *beds.* These seem to be viewed as an impedance to fishing rather than providing a nursery area for fish. Additionally, their removal on a large scale would only trigger a replacement by other macrophytes or, more disastrously for the biodiversity of the lake and the fishing industry, dominance by algal species. Removal of macrophytes at observed biomass levels in Chilka lake has little control over nutrient balances. Only 0.1% to 0.5% of plant biomass contains phosphorus compounds (Loenen and Koridon 1978) and removal on a large scale would also remove large numbers of invertebrates and fish.

Catchment management plans

The previous sections on nutrient budgets and sediment loading lead to the concept of catchment management plans. The first process is planning the catchment area use. Scotland, for example, has planned afforestation strategies. These plans in consultation with other land-users, including nature conservation interests, put afforestation alongside agricultural needs, wildlife interests, and sensitive areas for fisheries. Part of the strategy targets afforestation away from the most productive agricultural land and the most important areas for fishery and nature conservation interests. Where afforestation takes precedence over such interests, the forest is planned to have the least harmful effects. Only poor agricultural land is targeted; in sensitive areas for wildlife, deciduous hardwoods such as oak and ash are planted in preference to conifers, and sensitive fisheries are buffered from the effects of acidification by deciduous streamside planting (Forestry Commission 1992). Statements of intent are produced from these consultations and they are written as a catchment management plan for the area.

Socio-economic studies

Socio-economic studies are becoming very important in the British Isles in assessing the likely effects on the social environment and rural economies of particular impacts. Rural economies and farming practices in western and northern Britain help sustain wildlife interests. Some of the most extensive and natural wetlands are maintained by sympathetic farming in these areas. Unlike India, compensation payments are invariably made to farmers to maintain their farming practice and so sustain rural economies. These zones are designated as environmentally sensitive areas.

Damage to the environment as well as the communities within it arises from large-scale projects where the controlling body may be a large multi-national company or owner with interests not local to the area.

The Flow Country in Caithness, Scotland, is an internationally important area of blanket mire covering 4000 km^2. Private afforestation schemes were only allowed because it was argued that they would provide jobs for local communities. Some 60 000 ha have been planted or have been grant-aided for planting. There is a minimum planting target of 100 000 ha (1000 km^2). It is very poor ground for trees, by definition very waterlogged, so only the higher ground has been planted. Additionally, some of the areas are so exposed that these are designated wind blow areas where whole forests could be felled in one gale. Planting is not allowed in these areas. The result is a patchwork of forests affecting the landscape interest of larger areas and the hydrology of the blanket mire. Initially, jobs were available to help in the tree planting but the forest is now growing and needs little attention. The patchwork nature of the lodgepole pine (*Pinus contorta*) and sitka spruce (*Picea sitkensis*) coniferous forest on a blanket mire, where there has been no recorded history of previous natural afforestation, has adversely affected grouse shooting, stag hunting, and salmon fishing, the last due to apparent reductions in river levels and fish stocks. The income from the forest and grant-in-aid to plant the trees goes to the owners, the majority of which live outside the area. The forests, rather than creating jobs and increasing the wealth of the area, may have taken money from the area (R Lindsey, personal communication 1993). This was predicted in a socio-economic appraisal commissioned by the Nature Conservancy Council when it tried to defend the area between 1987 and 1989. Not all areas have been affected and over half the area is or will be protected in law under the Wildlife and Countryside Act (1981).

Bhitarkanika, Orissa

Parts of the reserve at Bhitarkanika are being exploited by the local people. Mangrove is being felled for firewood and housing construction. Monocultures

of coppiced *Phoenix paludos* are being encouraged to grow in their place, their leaves providing roofing material and bedding for cattle.

A socio-economic study could investigate the importance of mangrove in providing a first line of natural defence against cyclones. It could also illustrate the potential increase in incomes in diversifying agriculture away from a monoculture of rice already suffering depressed prices due to over-production. Fish farming in small village ponds would be a valuable source of protein. Orchards could be planted, their fruits would be a valuable source of fibre and vitamins (Kar 1993). Saline areas close to rivers could be encouraged for local prawn culture, a valuable cash crop. Diversifying agricultural production and increasing income could reduce the reliance of farmers on the mangrove system.

Chilka lake, Orissa

Chilka lake is exploited as a fishery; its plant production is used as cattle feed; some prawn culture is carried out locally; and it is used as a receiving water for urban sewage, agricultural pollution, and light industrial pollution.

The lake is also threatened with sedimentation or delta formation at its inflow and is exhibiting the first stages of eutrophication in local areas (see previous section on sediment loadings). Turnover times or retention times of the lake water could be lengthened by the impedance to flow at its inflow and outflow, thereby exacerbating the local eutrophication process.

Fish production for eutrophic over-fished brackish water lake in the Mediterranean was approximately 50 kg/ha (Newbold and Freisi 1990); Chilka lake had a maximum of 86 kg/ha, which is now reduced to 59 kg/ha, the catches reducing from 10 000 tonnes/year to 6000 tonnes/year over a period of ten years (C R Das, personal communication 1993). Das also states that the fish are getting smaller. This is a well-recognized sign that the fishery is being over-exploited.

Fish production for some of the species present will be further reduced if the eutrophication process is not reversed, but its fertilizing effect may increase the growth rate and production of other species in the short term.

Intensive prawn culture within the lake is being proposed by a large multinational company. This would undoubtedly increase eutrophication and may increase the fish production of certain species with the extinction of other species. However, uncontrolled and continuing eutrophication from intensive prawn culture may well have an overall deleterious effect in the long term on fish stocks, thereby reducing one source of local income. Economically, large-scale prawn culture could have advantages as well as disadvantages for the people in the area. (For comparison with the Flow Country, Scotland, see previous section.) A fisheries study and socio-economic study is necessary. The aim should be to achieve a sustainable use of Chilka lake whilst maintaining its present biodiversity.

Conclusion

The nature and extent of wetlands in India is variously described, but an overall national inventory is lacking. The approach used in Britain might be adopted as one way of producing not only an inventory but a method of typing, describing, and placing them in a regional, national, or international context.

The maintenance of biodiversity in a wetland is often dependent on many factors. Five are considered to be more important than others: hydrology, nutrient status, sediment loads, catchment use, and socio-economic aspects. The first three research themes are seen as essential components in understanding a wetland. Catchment studies and socio-economic studies are necessary for integrating, and perhaps altering, the resource use of the area and the wetland into one that sustains its natural biodiversity.

Appendix 1

Research priorities in the British Isles: water quality priotities

Effects of

enrichment, nutrient budgets
acidification
pesticide drift
aquatic herbicides
fish farming
industrial pollutants
saline intrusion
iron rich and acid soils

Appendix 2

Research priorities in the British Isles: water quantity priorities

Effects of

land drainage on water levels and siltation
afforestation
abstration/irrigation
groundwater
climate on water flows
sea level rise
use of soft sea defences (natural value of wetland)

Appendix 3

Research and survey priorities in the British Isles

Research into water/land-use

- land-use change: loss of wetlands
- navigation
- recreation
- hydro-electric power

Research into socio-economic issues

- catchment planning
- integrated management studies
- sustainable use
- functional analysis of wetlands

Others issues

- restoration ecology
- a national vegetation classification

References

Bailey Watts A E, Sargent R, Kirika A, Smith M. 1987
Loch Leven phosphorus loading.
Midlothian, UK: Institute of Terrestrial Ecology. [Project 926]

Cuttle S P. 1982
Sources of nitrogen in surface waters within the catchment of Loch Leven.
Edinburgh: Nature Conservancy Council. [Report of the work done by Soil Science Dept, Edinburgh School of Agriculture]

Driscoll R J. 1983
Broadland dykes: the loss of an important wildlife habitat.
Transactions of the Norfolk Norwich Natural Society 26(3): 170–172

Forestry Commission. 1992
Guidelines on forestry and freshwater.
Edinburgh: Forestry Commission

Ghosh A K. 1989
Wetland ecosystem in India.
Management of Aquatic Systems ?: 141–153

Gibson C E, Wood R B, Drebson E L, Jewson D H. 1971
The succession of phytoplankton in Lough Neagh 1968–1970.
Mittelungen der Internationalen Vereinigung fur Theoretische und Angewandte Limnologie 19: 145–160

Gosling L M. 1971
Calthorpe water acidity: background, effects, cause and suggested treatment.
Norwich: Nature Conservancy Council. [Unpublished report]

Gosling L M and Baker S J. 1980
Acidity fluctuations at a broadland site in Norfolk.
Journal of Applied Ecology 17: 469–490

Kar K. 1993
Participatory rural appraisal for understanding the man environment conflict and its impact on the loss of biodiversity of wetland ecosystem at Bhitarkanika mangrove area in Orissa.
[REM/93/006/Kar]

Loenen M and Koridon A H. 1978
Role of littoral vegetation in the phosphorus and nitrogen balance of the Lake Drontemeer.
Verhandlungen Internationalen Vereinigung Limnologie 20: 935–938

Lund J W G. 1972
Eutrophication.
Proceedings of the Royal Society B 180: 371–382

M o E F (Govt of India). 1992
Conservation of wetlands in India.
New Delhi: Ministry of Environment and Forests. 48 pp.

Moss B. 1983
The Norfolk broadland: experiments.
Biological Review 58: 521–561

Moss B and Leach R T. 1982
Changes in the ecosystem of a guanotrophic and brackish shallow lake in eastern England: potential problems in its restoration.
International Review Ges Hydrobiology 65: 625–659

Newbold C and Freisi E. 1990
The Messolonghi wetlands—a discussion paper.
Peterborough, UK: Nature Conservancy Council. [Report for the European Commission]

Newbold C and Withrington D J K. 1989
Study on freshwater quality.
[Evidence submitted by the Nature Conservancy Council to the Royal Commission on Environmental Pollution]

Par M P and Smith R V. 1977
The identification o phosphorus as a growth limiting nutrient in Lough Neagh using bioassays.
Aquatic Water Research 11: 995–998

Phillips G L. 1984
A large-scale field experiment in the control of eutrophication in the Norfolk broads.
Water Pollution Control 83: 400–408

Phillips G J, Eminson D, Moss B. 1978
A mechanism to account for macrophyte decline in progressively enriched freshwater.
Aquatic Botany 4: 103–126

Ratcliffe D A. 1977
The Nature Conservation Review, vol. 1
Cambridge: Cambridge University Press

Remane A and Schlieper C. 1971
Brackish water as an area of colonisation of freshwater and marine organisms and specific habitat of brackish water organisms.
Die Binnengewasser, vol. 25: *Biology of Brackish* water. 2nd ed.

Soutar R G. 1989
Afforestation and sediments in British waters.
N C C, 5: 2

Wildlife and Countryside Act. 1981
Department of the Environment/Welsh Office, Her Majesty's Stationery Office

Socio-economic reflections on the field visits and workshop on wetlands biodiversity

M Walkey
The Durrell Institute of Conservation and Ecology
University of Kent, Canterbury, Kent, Great Britain CT2 7NX

The future of biodiversity within natural ecosystems depends crucially upon decisions taken by people. These decisions, whether local, national, or international, are primarily economic, social, cultural, and political.

In mega-diversity countries, of which India is one, choices for decision-makers are presented in sharper relief than they are for nations with less rich and varied natural resources. This has led to an apparent tendency to consider decisions about environmental management as a polarized choice between conservation or development. However, it is now apparent that, either on global or on subsistence-economy levels, the preservation of biodiversity is a practical problem that can be successfully achieved only if the social, economic, and political context is fully taken into account.

The principal feature common to all the wetlands considered during the Workshop was the need for an integrated planning and management on the basis of

- *resource evaluation*
  biotope
  conservation status
  socio-economic appraisal
- *action plans*
  threatened/endangered species
  habitat management programmes
  human resource development

These analyses will provide some basis for assessment of the costs and benefits of spatial displacement—the ultimate effect of development, whether planned or unplanned, in wetlands.

Factors leading to decrease in biodiversity of India's wetlands were identified

as (1) monocultural practices (rice, prawns), (2) overfishing, and (3) removal of associated flora owing to overgrazing or other means.

Factors enhancing the sustainable use of wetlands in general could be identified as (1) development of alternative agricultural practices, (2) provision of inexpensive, alternative housing materials, restoration techniques, education, training and other human resource development.

With these underlying themes, visits of the wetlands team at the Indo-British Workshop on Biodiversity were able to identify several components of wetland management that justified further socio-economic appraisal.

These are summarized and grouped into those of direct value, indirect value, and both direct and indirect value.

Direct value

- *Fisheries*
  Sea fishing with small boats; long lines; small nets
  Trawling; drift netting with larger gear by peoples from outside the local area
  Inland fisheries with seines and trawls
- *Water resources*
  Washing, bathing, drinking
- *Food sources*
  Hunting, poaching
- *Housing materials, firewood*
  Timber, thatching

Indirect value

- *Nutrient trapping*
  Investment for fisheries
- *Groundwater recharge*
  Investment for water resources
- *Bank stabilization*
  Protection of people, property, and invested effort
- *Sediment deposition*
  Sewage disposal, detoxification

Direct and indirect value

- *Cyclone and flood protection*
- *Transport*
  People and products: replacement value of road and bridges
- *Agri-/silviculture and aqua-/horticulture*

Rice cultivation, re-forestation, vegetables
Prawns, carp, *Tilapia*
Honey

- *Tourism*
  Naturalists and bird-watchers
- *Biological diversity*
  Investment for fisheries, forest, future exploitation

As has been recently suggested, the valuation of wetlands may be based upon direct, indirect, and non-use values. However, mangrove wetlands justify a total valuation approach with incorporation of the ecological linkages. The relative strengths of such linkages, originating from human exploitation of the system, are an important factor in reaching development decisions. There is no doubt that the Bhitarkanika mangrove system justifies such analysis.

The wetland team considered that a similar approach was relevant also to the Calcutta wetlands and Chilka lake. At the Keoladeo National Park, Bharatpur, the avifauna is highly diverse and unique. However, the management of the lake requires a specialized cycle of monsoon, drought, and irrigation. The successful maintenance of the reserve seems assured as long as this cycle continues. The team has elsewhere commented on the potential value of establishing a chain of wetland reserves associated with the national park.

In ascribing a meaningful value to India's wetlands, the corollary is that loss of those same wetlands will have massively greater impact since any ascribed value cannot be extrapolated with confidence.

Summary of recommendations: wetlands ecosystems

Sunita Kripalani
British Council Division, British Deputy High Commission
5 Shakespeare Sarani, Calcutta - 700 071

1 We are primarily aiming to manage wetlands, whether it be for biodiversity, food production, or any other purpose.

2 Most importantly, we need to prioritize our objectives for each wetland area, since some objectives may conflict with others. Some wetlands (for instance the Ramsar sites) may give biodiversity/conservation a high priority over at least some of their areas. Others may accord priority to drinking water and irrigation, fisheries, wastewater treatment, tourism, etc. Adoption of a range of types of protected area, following the IUCN (International Union for Conservation of Nature) categories (based on use-class), is needed.

3 Different wetlands have different management requirements. Fine tuning needs to be done to identify these, depending on functional aspects of the wetlands view.

4 A protective area network of wetlands needs to be identified. A survey of this should be done to prioritize and identify a series of wetlands of regional, national, or international importance.

5 In order to formulate an appropriate national wetlands and mangrove plan, a rapid survey of wetlands in 447 districts of India, with a standard set of parameters, is urgently needed to create a national database compatible with that of other countries/regions.

6 No issue can be tackled in isolation.

- An IRMP (integrated resource management plan) for the wetlands that will incorporate social, economic, and ecological priorities and goals needs to be evolved. This should also include research and development needs, e.g. pisciculture, agriculture, agro-forestry programmes, and income generation schemes for people.
- An inter-agency collaborative approach is urgently needed both during the wetland/mangrove survey and during the formulation of the IRMP

for each state and union territory of India.

- The various government departments involved need to work closely together and in a more co-ordinated manner.
- In some cases, decentralized policy and planning may be advantageous. In others, national policies may be more effective in conserving biodiversity.

Any level of policy and management must involve people, in particular the NGOs (non-governmental organizations). Only then can development be sustainable. The NGOs need to be informed and made aware through seminars and discussions, training, literature and audio-visual aids, and networking. They should also be trained to take into .consideration the participation of women, health issues/parameters, income generation schemes, generation of public support, dissemination of information, protection and management of the environment at a local level, etc.

7 Appropriate state laws should be formulated for the conservation and management of wetlands for ensuring biodiversity on the one hand and community interest on the other.

8 In view of increasing development pressures, special attention should be paid to conserve Bhitarkanika sanctuary (as it is a fragile ecosystem). More research is to be initiated to assess the impact of human activities on mangroves, especially the effect of air pollutants [NO_2, SO_2, SPM (suspended particulate matter)] and other selected studies relating to impact.

9 East Calcutta wetlands, being a classic example of multifunctional, peri-urban wetlands, need conservation measures and studies to assess the impact of reclamation so far made.

10 Research studies in the areas of aquatic plant communities and inter-relationship with avian and other faunal elements, impact of our pollutants on mangrove vegetation, specially SO_2, NO_2 and SPM, and impact of catchment area activities on the wetlands are urgently needed.

11 In some coastal wetlands like Chilka, tide gauge data (using space-based platform or other methods) need to be generated to understand the modalities of interaction of marine and freshwater system.

12 Taxonomic studies on aquatic vegetation and faunal elements and micro-biological studies should be included the thrust areas.

Deserts

Flora diversity of the Indian desert

M M Bhandari
Department of Botany, J N Vyas University, Jodhpur - 342 001

Introduction

The Indian desert is known as *maru pradesh* or *marusthali* in local dialect (derived from the Sanskrit root meaning the land of death—death not only of man and animals but of the entire biota it contains, including the diverse plant species). This, in other words, means that the erosion of biodiversity is an inherent tenet of this region. Therefore, these days when people all over the world are putting their untiring efforts in conquering the desert, those who talk of protecting and preserving the desert biosphere – the environment where the spectra of ecosystems collapse, resulting in catastrophic extinction of not only our *chinkaras* and black bucks, but a variety of plant species it contains – may, more often then not, be classed as crazy. In fact, man has broken contact with the ecological universe of the desert that existed before his culture developed. This destruction of the ecosystem has been done at human peril. The foundation of new ethics should be that all things, living or dead, including man, are inter-related and form the web of life. For this alone, if nothing else, we need to preserve the areas containing undisturbed ecosystems for our sustainable survival. We need to preserve, and keep invariate, samples of as many types of environmental complexes as possible. Each biotic province needs its own wilderness for comparative studies of used and unused land. Half of the world's nations have some or all of their land in arid or semi-arid zones. These lands, of variable, erratic, and sparse rainfall, though they account for nearly one-seventh of the earth's surface, harbour only 10% of the world's population. These areas, which are generally forbidding wastelands, are sun-seared, wind-scoured, and waterless, devoid of shade and shelter, carry a legendary image of hostility. Only those who inhabit such areas know the perils and discomforts of desert existence. The response of even a botanically trained person, visiting the Indian desert, is one of overwhelmed astonishment. The myriads of unfamiliar kind of plants, mostly

leafless and spiny, form a thorny scrub; and stunted and half-nibbled shrubs, with trees few and far between, give it a desolate and barren appearance. Yet it sustains a large plant diversity.

Extent of and habitats in the Indian desert

What do we really know about the Indian desert—the land and soil that make it up; the plants, and the animals that feed on them; and the myriads of the delicate ecological relationships among all these organisms? Despite the fact that everybody knows about the general environmental conditions prevailing in the desert, very little is known about their causes and effects. In a general way, we know the important desert species that grow but little about where and why. Similarly, there are many other questions. For example, what effect do all these organisms have on soil formations or germination of seeds and subsequent development of desert plants? Why are there less trees and more thorny shrubs in the desert? How many local genotypes of *sevan* and other palatable grasses are found in the Indian desert? There are many uncertainties involved in answers to these questions but we can at least be very sure that it is only the intimate knowledge about life and activities of the desert plants that can help us preserve the disappearing species and depleting habitats of the desert.

The Indian desert, which occupies nearly 300 000 km^2 of hot desert, is situated in north-western India. Though the main part (61%) of desert lies in the state of Rajasthan, it also extends to some parts of Haryana and Punjab in the north (9%) and Gujarat in the south (20%). In the west, it merges into the fertile plains of the Indus river in Pakistan. Essentially, it is a sandy desert. Most of its area consists of dry undulating tracts of hardened sand. The rest is largely a rolling mass of loose sand, forming shifting sand-dunes of longitudinal and transverse types. The monotony of sand is broken by isolated rock exposures and the barren, melancholy outlook by the vividly colourful life. The whole area, which is approximately 100 metres above the mean sea level, is roughly rhomboidal. Physiographically, it is the eastern extension of the vast Saharo-Thar desert (Bhandari 1978, 1990).

The biodiversity of the desert ecosystem is intimately associated with the habitat diversity. Each one of the various habitats and land forms in the desert supports distinctive types of plants. For conserving the biodiversity of the desert, all these different habitat niches have to be conserved *in situ*.

Biodiversity related to the evolutionary history of the desert

The evolutionary history of the desert is directly related to the present biodiversity of this region. Although the exact time of its origin and the various factors that led to the present-day desert conditions are still not very clear, the

Thar's evolutionary history, from the geological point of view, is fascinating. Right from the early Triassic period, the area was under sea. Twenty million years later, the sea withdrew, due to uplift of the sediments. In the early Jurassic period, this place abounded in gymnospermous jungles. That was 180 million years ago. Twenty-five million years later, the area again came under sea. During the lower Cretaceous period, between 135 million and 63 million years, the area became a land mass with forests. This was followed by yet another invasion of the sea, when rocks containing marine fossils were deposited. Sixty-three million years ago, at the end of the Cretaceous period and the beginning of Cenozoic period, the sea took over again, inhabited by foraminifera and other tiny unicellular, shelled organisms. Their accumulation at the bottom of the sea and their ultimate decomposition is believed to be responsible for the formation of oil and natural gas. The sea finally withdrew from the desert about 35 million years ago. Being under and out of the sea at least four times during the last 280 million years has indeed left the illusion in some parts of Jaisalmer of a receded tide, gone but never returned, leaving great stretches of thirsty land, punctuated with sand-dunes in systematized curves. Though the origin of arid condition is said to be the climatic oscillation that took place in last phase of glaciation, during the Pleistocene period, the rise of the Himalayas, the extra-peninsular rivers changing their course westwards and the monsoon shifting eastwards, resulted in the creation of the arid conditions, now forming the Indian desert (Bhandari 1991). There is evidence to show that a well-knit river system existed in the desert until recent times. Once the geoclimatic events resulted into a warmer and drier area, man, with his hungry herd of goat and sheep and his ever-sharp axe, accentuated these conditions down the ages.

Thus, the plant life in the Thar has evolved over millions of years. Changes in climate, changes in the extent of land and water bodies through transgression and regression of the sea (Dhir *et al.* 1992), and recently the excessive exploitation of plant resource by man, have brought about many changes in the distribution and characters of the plants primarily associated with the socio-economic traditions of human survival. The presence of numerous fossils of fruits, leaves, tree trunks and stems suggests phases of cool temperate and warm temperate, and warm humid and sub-humid climates in the region (Lukose 1977). Where the species are now predominantly xerophytic, there existed semi-evergreen forests (Vishnu-Mittre 1977). The present-day vegetation, with a high endemism of the flora, is suggestive of a long arid period during which they have evolved.

The present-day Indian desert vegetation represents the paroxysmal form of the original environment that has evolved by a very slow deterioration. Plant life has been gradually transformed until it has disappeared, contributing to the

worsening climate conditions and finally creating absolute desert. The Indian desert was not as it is today; that in a not-too-distant past it was covered with thick vegetation is proved by the petrified remains of large tree trunks as are found only a few kilometres away from Jaisalmer in the Akal Fossil Park.

Present phytobiota of the Indian desert

The present phytodiversity of the Indian desert has western as well as eastern affinity (Bhandari and Mertia 1980). An analysis of the flora of the Indian desert shows a very complicated phytogeographical pattern. Numerous taxa have originated in the Indian desert where they are now isolated as endemics. Many others seem to have been extended into the Indian desert from diverse distribution centres. The overall distributional pattern of the desert biota indicates the migratory routes of the desert plants in the past. It seems that west-to-east migration should have started from Sahara. Many plant species, such as *Barleria acanthoides*, *Dipterygium glaucum*, *Dignathia hirtella*, and *Leptadenia pyrotechnica*, are restricted up to Thar while a few others, such as *Arnebia hispidissima*, *Tecomella undulata*, and *Orobanche cernua* var. *nepalensis*, have extended to most parts of India. A similar pattern of migration and distribution is met within the forms speculated to have migrated from Iranian region. Species such as *Aristida hystricula*, *A. pogonoptila*, *Blepharis sindica*, *Calligonum polygonoides*, *Dipcadi erythraeum*, *Haloxylon salicornicum*, and *Tamarix aphylla* are examples of this type. While these plants find their eastern limit in Thar, some (e.g. *Haloxylon recurvum*, *Corallocarpus epigaeus*, *Leucas urticaefolia*, and *Pergularia daemia*) extend to other semi-arid regions of India. It is remarkable that the number of Afro-Tharian elements in the flora of the Indian desert is appreciably high, which indicates that in the Indian desert, the migration has been mostly from Africa. Out of 209 plant species common to Africa and Thar, 60 are distributed up to Thar while 149 extend to other parts of the Indian subcontinent. Migration from the eastern side of the Thar accounts for 123 species, and the numbers from Malayan, Sino-Indian, and Australasian–Indian side are 12, 11, and 15 respectively.

Endemics

Of the plant taxa endemic to Thar, 23 are species and 14 are subspecies, forming 6.4% of the number of species. High endemics and occurrence of a large number of subspecies provide evidence of high phylogenetic plasticity (Mani and Singh 1963, Roonwal and Chotani 1965) and intense speciation on account of the extreme dynamics of the ecological conditions and recent geological, physiographic, topographical, and altitudinal changes. When these endemic figures of the Indian desert are compared with those in the flora of Sahara (Quezel 1965),

the results are interesting—only 3 to 5% endemics have been reported from that region. The high percentage of endemic species (6.4%), especially when the Indian desert is estimated to be only 10 000 years old, is difficult to explain. The evolutionary process for a species or subspecies is a long-term phenomenon and cannot be completed in such a short period. It is, therefore, possible that either the age of the desert, from biological evidence, is more than that estimated by geologists and archaeologists or the process of speciation has been activated due to rapid ecological changes in the past. The third speculation is that aridity established itself much earlier and the biota started evolving gradually.

Most of the species endemic to the Indian desert may not be important from the point of view of the origin of cultivated plants and, therefore, may not have obvious economic value at present, as the same has not been perceived yet. However, with the changing patterns of our needs regarding food, fodder, fuel, fiber, shelter, and medical care, we cannot foretell what species would be needed when. Who could have imagined a few years ago that the desert euphorbias of California would be a possible source of hydrocarbons? There is, therefore, an urgent need to arrest species extinction. It must be understood clearly that the gene erosion in contrast to soil erosion is not ordinarily perceptible and has therefore received inadequate attention from planners and bureaucrats, who are often oblivious to this urgency.

Value of biodiversity in the desert

The diversity of biota, particularly the genetic diversity of the desert plants, which provides an edge in the constant evolutionary mechanism of the desert-adapted plants, is of immense value in increasing the yields and coping with changing environmental conditions. The opportunities and scope provided by genetic engineering, which allows the transfer of genes among the species, will further increase the opportunities which the genetic diversity provides for enhancing agricultural productivity. For example, the occurrence of natural hybrids between *Citrullus colocynthis* and *Citrullus lunatus* can open new vistas in improving the productivity of the watermelon.

Thus the diverse array of genes, species, and ecosystem is a resource that can be tapped as human needs and demands change since biodiversity is so closely intertwined with human needs. Therefore, conservation of biodiversity at all costs should rightfully be considered as an element of national security. National security will be the strongest in countries that care for their biodiversity. Biodiversity is closely linked to cultural diversity since human cultures are in part shaped by the living environment that they in turn influence. The wide spread of Jainism and the Jamboji's Bishnoi sects in the desert, which preach respect for the diversity of life and concern for its conservation, is an instance of this.

Biodiversity conservation seeks to strengthen the human life-support system provided by nature in the desert environment and the available living resources essential for its development.

Species diversity

Species diversity refers to the variety of species within a region. Such diversity could be measured on the basis of the number of species in a region—its 'species-richness' or taxonomic diversity, which considers the relationship of species to each other. An examples of species diversity is the genus *Tephrosia*, which consists of nearly twelve species, most of which occupy different ecological pockets within the desert. Most of these species are closely related to *Tephrosia purpurea*, which itself shows a number of distinct populations. Some new endemic species such as *T. faciformis* and *T. uniflora* var. *petrosa* have also been described from the Indian desert. Similarly, there are large number of species and infraspecific taxa, including some new endemic taxa belonging to the diverse genera such as *Lasiurus*, *Tribulus*, and *Convolvulus*, which provide ample examples of species diversity of desert plants.

Genetic diversity

Genetic diversity refers to the variation of genes within a species. This constitutes distinct populations of the same species or genetic variation within populations or varieties within a species. Each variety within a species contains unique genes, and the diversity of genes within a species increases its ability to adapt to pollution, diseases, and other changes in the environment. When these varieties or populations of these species are destroyed, the genetic diversity within the species is diminished. The planet's natural wealth lies not just in its species, but in the genetic variation within them. Until recently, measurements of genetic diversity were confined mainly to domesticated species and populations. With modern biotechnological methods, where genes of wild relatives of cultivated plants are introduced in domesticated plants, this technique is proving to be of immense potential. Genetic engineers can use these genes to develop medicines and foods. In the Indian desert, there are numerous populations of a number of genera such as *Tephrosia*, *Citrullus*, *Cucumis*, *Tribulus*, *Convolvulus*, and *Lasiurus*. The genetic diversity present in them could be used in improvement of these plants for their better utilization. To give one example, there are a large number of strains of *Citrullus colocynthis*, locally known as *tumba*, an important sand-dune stabilizer found throughout the desert, spreading on loose sand. However, in the last fifteen years, ever since its seeds began to be collected for oil, it has become a threatened plant in the desert. Moreover, a natural hybrid between *C. colocynthis* and *C. lunatus*, the watermelon, has been found in the

Indian desert. Therefore, there is a possibility of transferring disease resistance and hardiness to the watermelon.

Ecosystem diversity

The arid ecosystem is a major and a distinct type of ecosystem, within which there exist different land-forms that constitute this ecosystem. These land-forms are an important source of biodiversity in this zone, particularly because they have a long history of exogenic and endogenic activities. The exogenic processes within the desert are the result of fluvial and aeolian activities. Hilly or rocky and gravelly pediment, flat buried pediment, older and younger alluvial plains, river bed, etc. are the products of fluvial processes. On the other hand, the formation of sand-dunes, undulating sandy tracts, and inter-dunal plains is the result of alluvial activity. The progressive burial by sand has reduced the spatial extent of fluvial land forms in course of time. On the basis of their age, mode of formation, and their stability, the sand-dunes may be classified as longitudinal, transverse, parabolic, or obstacle dunes. All these different land-forms support varied and specific vegetation. Therefore, biodiversity in the arid zone should be viewed and studied with reference to land-forms and the vegetation they sustain. Ecosystem diversity, in contrast to the species or genetic diversity, is hard to measure since the boundaries of the communities that constitute the various sub-ecosystems within the desert are elusive.

Ecosystem diversity could best be understood if we study the communities in various ecological niches within the desert ecosystem, each associated with definite species complexes. Each community has its own relative abundance of species and population complex. These complexes are all related to the composition and structure of biodiversity. Habitat destruction has dangerously narrowed the genetic variability of many species, cutting their ability to adapt to a number of adversities, which they can possess if allowed to grow in different habitats.

Biodiversity of the desert and human health

Once, all medicines used to come from plants and animal resources. Worldwide, medicines from plants are now worth 40 billion dollars a year. Even now, 80% people in the developing countries depend upon traditional medicines. Penicillin and tetracycline are amongst the 3000 antibiotics from microorganisms and the recent discovery of cyclosporin from a soil fungus has revolutionized the heart and kidney transplant surgery. (WRI, IUCN, UNEP 1992).

The Indian desert contains a large number of species, such as *Commiphora wightii, Withania somnifera, Urginea indica,* and *Solanum surattense*, which are all of immense medicinal value. The bulbs of *Urginea indica* from the Indian

desert, though smaller than those from the more humid samples, are richer in the total glycoside contents. (Gupta 1988).

Nagori *ashgandh* (*Withania somnifera*) roots have been mentioned to be more valuable than other samples. The variety WS-20 of this species, released for commercial cultivation, is probably from this biodiversity region. There, however, exists another rare and endemic species of *Withania* (*W. coagulans*), locally known as *panner-bandh*, which needs further studies in this regards.

Comniphora wightii, the *guggal* plant, is another important medicinal plant of the desert, which apparently has become a threatened plant due to over-exploitation as a result of ignorance and greed of the people, particularly during famines. The demand for *guggal* gum is estimated to be 300–500 tonnes annually. In 1986, India had to import 50 tonnes of this gum from Pakistan (Gupta 1988). *Guggal*, an oleo-gum resin, which has long been used in ayurvedic medicines, has of late attracted attention for its anti-inflammatory, anti-rheumatic, and hypocholesterolemic/hypolipaemic activity. The Anand Centre has collected 55 populations and the agriculture college at Jobner collected 58 samples of this plant from 11 districts of Rajasthan. A proper evaluation from the point of view of productivity will enable the best available strain to be chosen for commercial cultivation. Similarly, the estimated demand for 500 tonnes of *Solanum surattense* (*S. xanthocarpum*), a ruderal weed of the arid zone, can open up new vistas for economic development in this region.

There are as many as 200 species of plants of minor medicinal uses in the desert and there are many others the medicinal usefulness of which is yet to be established. This plant diversity of the desert ecosystem has immense prospects.

Biodiversity related to human culture in the desert

The biodiversity of the desert has yet another important component, namely its human cultural diversity. Nomadism and pastoralism are the essential components of the desert ecosystem due to frequent famines, which pose numerous problems of survival in the desert for man as also for animals and plants. Due to harsh and rapidly changing environmental conditions in the desert, people have evolved different religious beliefs, diets, and land management practices.

They have developed lifestyles best suited to the available natural resources, thereby enriching the biodiversity of this region. They have linked various cultural codes and biodiversity with their collective survival. *Orans* and *gochars* were created and preserved under collective control. Certain plants of the desert were considered as deities and rituals to honour the deity served to preserve their diversity. In the face of recurring scarcity or famines, year after year, the native people of the desert have developed a survival ethic in consonance with the ecological culture in the desert. They draw their sustenance from scattered wild

plants by collecting seeds, roots, tubers, and even bark of some of these wild plants that are the only easily available food for them in such times (Bhandari 1970, 1988). These food habits are a result of a long-standing struggle against nature, which overcome the effects of deficiency or failure of rains that, in other regions, would have caused serious and widespread distress. There are many plants of great importance as emergency foods but, after centuries of use, the regenerative power of these plants has decreased considerably. As a result, on the one hand their market value has increased enormously, leading to over-exploitation; on the other, it has gradually resulted in the depletion of these resources. Exports and prices over last two decades of *sangari* (young pods of *Prosopis cineraria*), *ker* (young fruits of *Capparis decidua*), *kumbat* (seeds of *Acacia senegal*), *gawar* (immature dried pods of *Cyamopsis tetragonoloba*), etc. have sky-rocketed. Thus, this diversity, which has been preserved and maintained by them, has become a source of exploitation since the material they have preserved through centuries of sustenance has gone to the hands of the elite.

Causes of biodiversity loss

The loss of biodiversity in the Indian desert is mainly due to its inherent eco-cycle and a number of endogenous and exogenous processes, which have accelerated the erosion of valuable germplasm stock. The main causes of degradation and depletion of biodiversity are discussed below.

Recurring droughts

As in all deserts of the world, droughts are inevitable in the Thar desert. The climate of the desert has one certainty: sooner or later, there are long droughts. These droughts have been a feature of the desert for centuries and will continue to be so. In fact, these famines have been regarded as a grand natural disease of the desert since they lurk for ever at the door of the desert. In the desert, droughts are not perceived as tornadoes or earthquakes; they are accepted as a harsh fact of life. Despite their regular occurrence, the droughts always bring death and dislocation in the desert. Apart from human and animal suffering, droughts, which result in famines, destroy the vegetation cover in the desert. During droughts, the animals in the desert eat every blade of grass on the weather-degraded rangeland until they starve to death. The tree-climbing goats eat the last bit of greenery, leaving behind wooden skeletons for the gatherers of firewood. The pockets of vegetation and patches of rangelands are severely degraded. When land abuse is severe and prolonged, especially when the droughts recur in successive years, the effects are accelerated. The grass and vegetation cover of other habitats is lost, leaving only stony, eroded wastelands. More commonly, the quality of rangeland vegetation declines as the more

palatable and productive plants are nudged out by less desirable species. Despite the effects to thwart desertification, the damage continues irreversibly. Worst-hit by the droughts are the wild plants and, after recurring droughts for four to five years, the desert has earned itself the distinction of being the worst habitat for plants in India.

Biotic interference

In addition to these recurring droughts, the area of the entire desert has been subjected to severe biotic interference since ages. The fragile ecosystem of the desert has been under severe stress continuously by its ever-growing human population. The Indian desert is the most thickly populated deserts of the world. From 1971 to 1981, its population increased by 37%. The estimated figure by the turn of the century is 22 million. As a net result of this, natural resources are being depleted much faster than they are regenerated, ultimately resulting in reduced productivity. The trees, shrubs, and even their roots are indiscriminately removed by the rural poor for fuel, feed, fencing, and construction. The pressure of population further increases during droughts when even normally untouched plants like *Euphorbia caducifolia* are removed for fuel and even as goat feed because nothing else is available. Lopping, coppicing, and amputating the branches of trees degrade the vegetation. The requirement of woody biomass for fuel purposes alone has increased from 1.85 million tonnes in 1951 to 4 million tonnes in 1991. Each family of an average of five persons destroys more than one hectare of woody plants per year. The main target species for fuel are *Prosopis cineraria, Acacia nilotica, A. senegal,* and *Calliqonum polygonoides.* The digging of the roots of *C. polygonoides* has severely threatened the ecosystem since this species is a great sand-dune stabilizer.

Grazing pressure

The Indian desert has also more than double the recommended bovine grazing population. Hungry herds of camel, sheep, and goat reduce the local shrub formation and thus deteriorate the natural vegetation by over-exploitation. In the desert, where farming is difficult and unpredictable, animal husbandry is one of the most important occupations. Rearing livestock is one of the functional specialities of certain castes and communities on which they rely upon for their sustenance—grazing animals are treated as members of the family.

It is well known that the number of camel, sheep, and goat grazing in the Indian desert is much beyond its carrying capacity and a careful study by experts shows that it cannot support even half the existing number without damaging the desert vegetation beyond repair. As a result of such excessive grazing, the natural vegetation is not only damaged, but is gradually being reduced in quality.

It is seen that due to intense grazing, a serious change is coming about in the desert. This is amply and aptly summarized in out local couplet *Unt chode akro* and *bakari chode khakro* [The camel ignores *Calotropis prosera* but the goat ignores only stones] .

Developmental activities

Presence of the armed forces, especially by constructing roads and consuming vegetative cover, has also destroyed a number of plant habitats. Military occupation, and exploration for oil and minerals in the desert, have to some extent been responsible for erosion of habitat in numerous smaller areas of the desert.

Conservation strategies

Conservation, defined as management for the benefit of all life, is increasingly recognized throughout the world as one of the most important aspects of preserving biodiversity. In context of the Indian desert, conservation of biodiversity is essential not only to maintain the most fragile ecological processes and life-support systems but also to ensure the sustainable utilization of the species as well as the ecosystem. (Bhandari and Shirangi 1986)

According to one estimate, at least one species is being lost every day and by 2000, one million species would have been lost. Extinction is a process that is continuous and irreversible. A number of plant species have already disappeared and others await a similar fate (WRI, IUCN, UNEP 1992).

Each forest or grassland has a particular form of each species and each form is specially adapted to a particular site where it grows. Differences between them can be identified and used for better management. Desert is, therefore, a tremendous storehouse of potential resources, not only for ecological or taxonomical research but also as a source of as yet unknown economic products from plants. Day in and day out, we read about a new antibiotic or a new drug from plant sources. The discovery of gugulip from *Commiphora wightii*, which reduced serum cholesterol, and diosgenin from *Balanities roxburghii* are two instances of such discoveries. We, therefore, need to keep inviolate samples of as many types of vegetation in as many situations as possible, and to keep from extinction as many species and genotypes as possible. Is there any one amongst us who could evaluate the potentials of *Schweinfurthia sphaerocarpa* or *Farsetia macrantha*? None of us can, for this scorph and this crucifer have almost disappeared from the Indian desert, and once extinct, no human effort can ever recreate these or any other species, particularly because they are rare or even endemic to this desert.

In situ *conservation*

Since most of these threatened plants occur as components of biotic or bio-edaphic communities in open sites, restoring climax vegetation in such habitats through judicious protection measures is required without further loss of time. Equally important would be to rehabilitate fast-depleting types in ecotonal zones since such sites provide wide ecological amplitude. Identification of such floristic niches within the biosphere reserve would assure their stability vis-a-vis preservation.

For *in situ* conservation, a biosphere reserve offers the best site of natural conservation of threatened flora. The concept of preserving biodiversity resulted in the Biosphere Reserve in 1974 as Unesco MAB (Man and the Biosphere) Project no. 8 for the conservation of the natural areas and of the genetic material they contain. The driving force for the creation of such reserves was the realization that natural ecosystems throughout the world were being altered on a massive scale. Therefore, the setting aside of representative sites inclusive of major ecosystem types became absolutely necessary.

The Government of India conceived the idea of establishing 13 biosphere reserves; the DBR (Desert Biosphere Reserve) was one of them. A comprehensive document to that effect was prepared and submitted in 1988 (Sankhala *et al.* 1988) by an expert committee of which the present writer happened to be a member. The proposed DBR has been envisaged to offer the best site for *in situ* conservation of the threatened flora of the desert. Unfortunately, to this date, this proposal has remained only on paper and has not seen the light of the day due to lack of political will on part of the state government.

Recalling that man and all animals are dependent for their survival on the plant kingdom; that plants (species, sub-species, varieties, etc.) form a genetic resource of immeasurable value to mankind; and that the economic potential of the plant kingdom is only partly realized, and also realizing that once a species becomes extinct, it cannot be recreated by man, it is of utmost importance to ensure the conservation of as many species as possible for the economic, scientific, and cultural benefit of mankind. A proper survey of the entire flora will reveal which plants are threatened, which are rare, and which are endangered in this region. This information has to be based on field surveys rather than only on the basis of literature and herbarium survey, as has been done in the past. This is necessary due to the fast-changing habitats and degradation of ecosystem which ultimately result in desertification.

Therefore, detailed mapping and a floristic ecological survey needs to be made within the biosphere reserve. In addition to the proposed biosphere reserve, small representative areas throughout the desert will have to be identified and recommended to be preserved against the destructive agencies through

legislations. Such areas should be set aside as *sanctum sanctorum* for the total preservation of depleting germplasm.

Ex situ *conservation*

However, the impracticability of advocating theories of plant reserves for the protection of the flora under climatic conditions of the arid region is quite obvious, specially because here the plants are represented by species scattered over hundreds of kilometers in the desert. An alternative to this is to start desert gardens, where conditions can be created that are more favourable for the conservation of those species which are in critical state.

Though there are several botanical gardens in our country, the natural genetic wealth, including wild relatives of cultivated plants, and rare and threatened plants, is not given priority over ornamental plants and other exotic flora in these gardens. Therefore, for *ex situ* preservation, special-purpose gardens should be established. The establishment of at least one desert garden, where all the desert plants could grow under semi-natural conditions and disseminate their seed and propagules for self propagation, is of great practical value. Practical conservation can always be effective through restrictions in collection and preventing them from being damaged by accelerated human use. Therefore, a national desert botanic garden should be created, in which all plants growing in the desert can be cultivated, propagated, and kept under conditions similar to those in natural desert. Bulking up such plants in the garden and re-introducing them is essential to restore the critically-low population.

Conservation through gene banks

In addition to *in situ* and *ex situ* conservation, long-term storage of seed as gene banks can also be undertaken. The National Bureau of Plant Genetic Resources, New Delhi, has already developed cold storage modules. Therefore, seeds can be sent to the Bureau for maintaining this diversity.

The area of conserving rare and threatened plants through biotechnological approaches is vital to the conservational needs of the country. It is necessary to have a well-conceived production programme for the conservation of plants that usually do not produce viable seeds in large quantities and therefore are under constant threat of elimination. Clonal propagation is now gaining recognition as a quicker alternative in conservation. *In vitro* techniques are being increasingly applied to supplement conventional methods of propagation.

Survey and research needs

As already mentioned, apart from the needs of a survey, the whole question of biodiversity and its conservation in this region needs basic research. To carry out

basic research, we must have natural or scientific areas, that is tracts of land in a natural state, set aside and permanently protected or managed to preserve natural plant or animal communities, free from any kind of interference that will destroy the community. Cultivated land as that of Ganganagar or grazed and over-grazed land as found throughout the desert, support different living things—the complex system has changed and with it the original value of the basic research is lost. Desert habitats need their own wilderness for comparative studies of used and unused lands. Of course it is too late now, particularly when man with his ever-sharp axe and hungry herds of camel, sheep, and goat has raped the desert for centuries, to salvage more than a lop-sided system of wilderness remnants, most of these far too small to retain their normality.

What, then, is the principal purpose of desert wilderness or desert scientific areas or desert biosphere reserve? It is here that we can preserve permanently the tremendous complexity of undisturbed natural biotic communities, so that we can further the understanding of nature, for the benefit of man, by basic research into the ecology, taxonomy, and economic uses of the organisms and to transmit such an understanding to students of this as well as later generations.

Recommendations

No research can help restore this biodiversity loss unless the major decisions are taken at the political level to govern and manage the whole ecosystem for sustainable development of the arid zone. We need to educate our local population that their short-term gain of natural resources today will turn out to be a major catastrophe of tomorrow. Pressure should be put on the state government to activate and effectively use the desert biosphere reserve for the conservation of biodiversity. Specific research projects for the purpose be prepared and experts of proven ability from different institutions be involved and their collaboration sought. Three groups, namely lower plants, early land plants, and higher plants, should be set up for this study. There is an urgent need for the establishment of a computerized database of all natural resources including the resources under cultivation. This work could only be completed by a team of personnel trained in taxonomy, herbarium techniques, ethno-botany, ethno-zoology, and ethnic practices in cultivation—all with reference to conservation of biodiversity. All methods of conservation, i.e. *in situ*, *ex situ*, *in vitro* culture, cryopreservation, and gene banks support, should be employed on priority basis, suiting different taxa and habitats. There is an urgent need for the establishment of a desert botanical garden. An action group of local experts should be formed, which should act as a focal point for monitoring of all activities regarding life-support systems for sustainable development of the entire desert ecosystem.

Conclusion

In general, the desert ecosystem poses difficult problems to man. Its extent is large, its nature is difficult, and its opportunities are limited or insignificant, particularly when we consider the effort and investment needed for its eco-development. Originally, this area had but a scant population. More often than not, for reasons rooted in their history, the population does not command the advanced technological and managerial competence required for the utilization of so difficult an environment.

It is true that to preserve and regenerate the proposed desert biosphere reserve, we have to enlist the active participation of the local population, which has to be educated to preserve and develop the area sustainably.

Unused and vast tracts of great beauty still remain in this desert, and these should be preserved, perhaps as national parks, before urbanization and industrialization leave a mark upon them. Tourism is developing in this desert, where visitors come to enjoy the solitude, silence, and serene beauty of the desert.

References

Bhandari M M. 1970
Famine foods of Indian desert.
Economic Botany ..3: 73–81

Bhandari M M. 1978
Phytogeography of the Indian desert, p. 143–152
In *Tropical Botany*, edited by Larsen K and Holm-Nielsen L B.

Bhandari M M. 1988
Life support systems for heat tolerance, p. 60–65
In *Life Support Plant Species*
New Delhi: National Bureau of Plant Genetic Resources.

Bhandari M M. 1990
Flora of the Indian desert, 2nd ed.
Jodhpur, India: M P S Repros. 435 pp.

Bhandari M M. 1991
Evolution of desert vegetation, p. 73–78
In *Thar Desert in Rajasthan: land, man and environment*, edited by Dhir P R et al.
Bangalore: Geological Society of India. 191 pp.

Bhandari M M and Mertia R S. 1980
Vegetation adaptation in extreme arid region of India Desert, p. 155–164
In *Arid Zone Research and Development*, edited by Mann H S et al.
Jodhpur: Central Arid Zone Research Institute. 531 pp.

Bhandari M M and Shirangi O P. 1986
Conservation of threatened plants of Western Rajasthan, p. 129–132
In *Environmental Degradation in Western Rajasthan*, edited by Mohnot S M and Bhandari M M.

Dhir R P, Kar A, Wadhwan S K, Rajaguru S N, Misra V N, Singhvi A K, Sharma S B (eds). 1992.
Thar Desert in Rajasthan: land, man and environment.
Bangalore: Geological Society of India. 191 pp.

Gupta R. 1988
Life support species for medicinal use in India, p. 181–190
New Delhi: National Bureau of Plant genetic Resources.

Lukose N G. 1977
Palynological evidence on climatic changes in Jaisalmer basin, Rajasthan, p. 31–41
In *Desertification and its Control,* edited by Jaiswal P L.
New Delhi: Indian Council of Agricultural Research. 358 pp.

Mani M S, Singh S. 1963
Entomological survey of Himalaya, part 26: a contribution to our knowledge of the geography of high attitude insects of the nival zones from north-western Himalaya
Journal of the Bombay Natural History Society 60: 160–172

Quezel O. 1965
Contribution a l'etudede i endemism chez les Phanerogames Sahariens
C R Somm. Seanec. Soc. Biogeog. 359: 89–103

Roonwal M L and Chotani O B. 1965
Zoogeography of the termites of Assam region of India with remarks on speciation
Journal of the Bombay Natural History Society 62: 19–31

Sankhala K S, Bhandari M M, Prakash I, Gosh P, Melhotra S P. 1988
Desert Biosphere Reserve
New Delhi: Ministry of Environment and Forests. 100 pp. [Project Document No. 7]

Vishnu-Mittre. 1977
Origin and history of the Rajasthan Desert: paleobotanical evidence, p. 6–9
In *Desertifications and its Control,* edited by Jaiswal P L.
New Delhi: India Council of Agricultural Research. 358 pp.

WRI (World Resources Institute), IUCN (International Union for Conservation of Nature and Natural Resources), UNEP (United Nations Environment Programme). 1992
Global Biodiversity Strategy, p. 5
Washington DC: World Resources Institute. 244 pp.

Strategies for conservation of biodiversity in the Thar desert

R N Kaul
National Afforestation and Eco-development Board, Ministry of Environment and Forests
Paryavaran Bhawan, C G O Complex, Lodhi Road, New Delhi - 110 003

Introduction

The Thar desert is an area that has long been occupied by man. By general arid zone standards, it has a high population density, which ranges from 263 persons per km^2 in Jhunjhunu to 9 persons per km^2 in Jaisalmer. The decennial growth rate of population during the decade 1981–91 in the desert was 29% as against 23% for the country (Government of India 1991). The livestock population increased from 9.4 million in 1951 to 14.4 million in 1961 (53% increase) and 15.52 million in 1971 (8% increase). The density of livestock per 100 ha of grazing lands increased from 72 in 1951 to 175 in 1971 (293% increase). The increase in bovines (cattle and buffaloes) and camels has been very high in this region. The percentage of net area sown in the Thar desert has been steadily increasing. It is, therefore seen that there is a move towards greater intensity of land-use with less control of grazing in some areas and an increase in the amount of cultivation on what was formerly reserve or common grazing land. There is much evidence in the region of past forms of land-use having deleterious effects on land and vegetation resources, and it would appear likely that the rate of degradation has accelerated in the last few decades.

Present status of biodiversity

Biodiversity

Because of its evolutionary history and geographical location, the Thar desert exhibits significant biological diversity. (Biodiversity is defined as 'The totality of genes, species, and ecosystems in a region or the World' (WRI, IUCN, UNEP 1992). While some biota possess Saharian affinities *(Haloxylon, Gazella doreas)*, others are Malayan *(Ficus, Mangifera, Pteropus giganteus)*, and still others are Deccanean *(Rattus cutchicus, Golunda ellioti)*. In addition, quite a few are

macro-endemic *(Stempdactylus orientalis, Gerillus geadowi)* and micro-endemic species *(Bangarus caerulens sindanus, Felis libyca ornata).*

Flora

The vegetation of the major part of the region is categorized as tropical thorn forest (Champion and Seth 1968). The density of natural cover is much less than the potential. The natural vegetation substantially contributes to the productivity of highly valued trees and shrubs such as *khejri (Prosopis cineraria)* and *bordi (Ziziphus nummularia)*, which are conscientiously maintained. Besides this, many shrubs and grasses are found growing in rangelands, fallows, and crop lands. These tree, shrub and grass species are well adapted to the environment, withstand the worst droughts, and yet are efficient in producing good quantities of biomass during favourable rainfall years. An estimated 682 plant species are indigenous, belonging to 352 genera and 87 families (Bhandari 1990). Genetic diversity is found both within a single species (e.g. *Citrullus colocynthis, Calligonum polygonoides,* and *Lasiurus hirsutus*) and among the species of a single genus (e.g. *Tephrosia* and *Tribulus*).

Fauna

The total number of animal species described so far from the Thar desert adds up to 470. Of these, 35 are fish, 5 are amphibians, 25 are reptiles (including 7 sub-species), 350 are birds, and 55 mammals (Prakash 1974). The number of species of plants and animals would surely increase with further survey and studies.

With the launching of the IGNP (Indira Gandhi Nahar Pariyojna), the flow of a large amount of water in the desert tract has caused significant adverse environmental changes, particularly waterlogging and soil salinity. This has led to replacement of original xerophytic species, particularly valuable rangelands of *Lasiurus hirsutus* (sewan). However, the spread of cultivation due to availability of water has added about 80 species of birds that were earlier not found in the area (Rana, personal communication).

Endangered species

The species of plants that need protection are *Citrullus colocynthis, Withania coagulans, Commiphora wightii, Caralluma edulis, Dipcadi erythraeum,* and a few grasses. In all, there are some 56 taxa of desert flora that need to be conserved lest they become extinct. Among the animals, six species of mammals, eight species of birds, and three species of lizard are listed (Annexure 1) as endangered (Sankhala *et al.* 1988), which need protection.

Conservation problems of biodiversity

The general problem of arid areas with large populations is essentially one of human ecology. These populations have tended to over-exploit their natural resources. Where large-scale water resources from outside the arid region cannot be tapped, the inherently limited water resources within the region set the ultimate limit of production of plant material on which both human and animal populations are finally dependent. Furthermore, erratic rainfall results in widely fluctuating production and this, in turn, leads to famines, imposing stress on these populations. As populations increase, these stresses become greater so that the demand on natural resources is magnified. Eventually, the consequence is an imbalance between the human and animal population on the one hand, and plant, water, and land resources on the other. As the demand by the first persists and increases, the resources tend to become depleted and, as depletion proceeds, the stress upon them becomes even greater. Thus, a process of progressive degradation of resources is set into operation, which intensifies in every famine and the period following it. If continued unchecked, it leads to permanent damage in the form of loss of valuable plant species through excessive grazing or cutting for fuel, which are replaced by bare land or, at best, less useful plant communities (Figure 1). The loss of surface soil by water or wind erosion, lower soil fertility, the conversion of large areas into wasteland cut up by erosion channels, or formation of barren sand-dunes which are unproductive—all result in loss of biodiversity.

The cumulative effect of all these processes is significant changes in both the hydrology of the region and its micro-climate, tending towards an environment which is more arid and less productive. The final outcome, if this process is left uncontrolled, will be an irreversible damage to biodiversity.

Conservation of biodiversity

The Thar desert has a folk tradition of conserving biodiversity. Khejadala village in Jodhpur district is an excellent example of local inhabitants zealously protecting plant and animal species. It is said that some 360 years ago in this village three Bishnoi women sacrificed their lives by hugging their *khejri (Prosopis cineraria)* trees rather than allowing them to be cut down (Malhotra 1986). Even today, the Bishnois vigilantly protect not only the *khejri* trees but also black buck, *chinkara*, *nilgai*, and peafowl around their villages. In addition, there are extensive *orans* (sacred scrub lands) where cutting of trees and shrubs is prohibited. Bara Bagh in Jaisalmer and Gajner in Bikaner are fine examples of *ex situ* conservation of biodiversity in the region and bear testimony to the concern the rulers of erstwhile princely states had for conservation and enrichment of biodiversity.

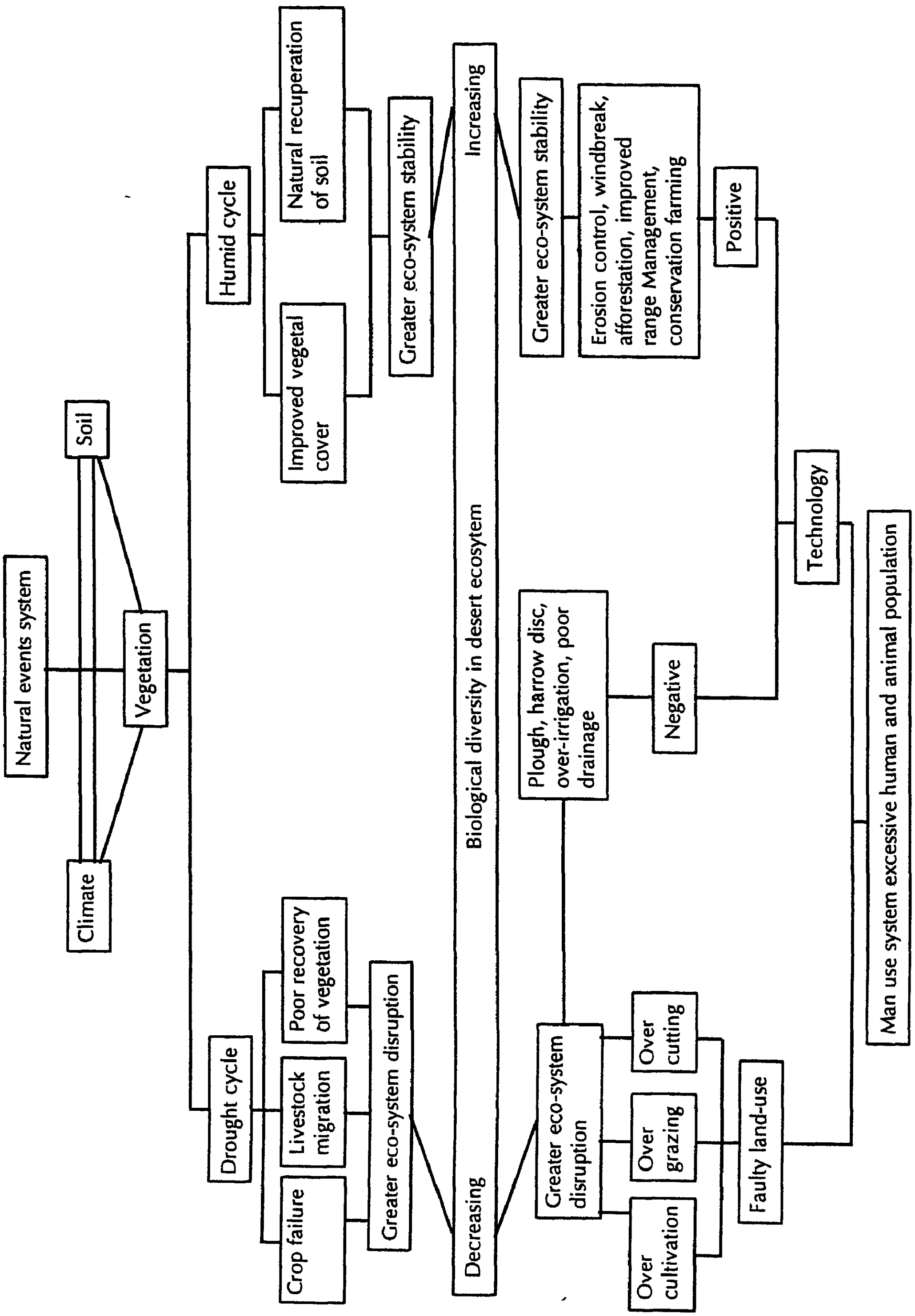


Figure 1. Factors affecting biological diversity in desert ecosystem

The two major nature reserves in the Thar desert are the Jaisalmer Desert National Park covering an area of 294 km^2 as against 3000 km^2 proposed earlier, which is no doubt inadequate, and the Wild Ass Sanctuary in the Rann of Kachchh, besides Tal Chapar and Gajner sanctuaries. These parks and sanctuaries hold the key to the conservation of this biota and should emphasize recreation of the natural biota through protection, and, if necessary, by deliberate re-introductions.

The tasks ahead

Biodiversity supports human survival in myriad ways, notably through health, food, and industry. It is lost or conserved at the local level. It is, therefore, imperative that effective conservation efforts begin in the fields, grazing lands, woodlands, and settlements where people live and work. The various issues and options, as related to the three main ecosystems, that could facilitate decision-making for biodiversity conservation are, therefore, discussed from a resource manager's perspective.

Grazing lands ecosystems

From the foregoing discussions, it is seen that the present state of much of the vegetation in the region would call for a substantial reduction in the number of animals. The overall conclusion is that, for long periods of the year, the rangelands badly need rest from the intensive grazing to which they have been subjected for decades. Under existing economic and social conditions, that rest can best be provided by holding nomadic and migratory flocks and herds for, say, one month longer in the cultivated lands (to which they go at regular intervals in many parts of the area), and by bringing them back to these areas one month earlier, an action which can be regarded as one step in the transition from a true free-range grazing of the nomadic types to a partially settled form of livestock husbandry and so also human life. The stock cannot be kept in areas under regular cultivation during the growing season as they would interfere with the sowing and harvesting operations. It, therefore, becomes essential to establish holding centres, probably along the fringes of cultivated zones. At these centres, enough fodder reserves would be grown or stocked to maintain the livestock for this period of a month, and for use in times of crisis. These centres could also be used to provide superior rams to the flock keepers in transit to the desert ranges in exchange for their inferior animals.

This brings us to the basic approach to land-use in the region, in all of which grazing represents the most important activity. Even though the rangelands have suffered considerably at the hands of nomadic and migratory graziers and their flocks and herds, there is hardly any integration of livestock husbandry in the cultivated lands. There continues the fundamental distinction between the

farmer and the grazier. The main objective must be intensive and full integration of crops and livestock to bring to the cultivated lands the much-needed manure through the droppings of millions of livestock, which are at present wasted on desert sands.

It is probable that only a combination of these approaches will help achieve the fullest realization and production potential of these areas. Under proper management, the extensive arid grazing land ecosystem would improve and greatly contribute to biodiversity conservation.

Where water points are few and widely distributed, there is inevitably a greater concentration of both human population and grazing animals dependent on each other than when the water points are more numerous. In consequence, there is also a greater intensity of cultivation and grazing and it is a common feature to find the area surrounding isolated watering points to be severely denuded and often bare and blown into the moving sand. Much of the migration of the animals in Jaisalmer and other dry districts is due to lack of water rather than lack of forage. In fact, well grown, little grazed, and little damaged grazing lands are seen in the driest parts of the region. An increased number of watering points will thus mean a more effective and regulated utilization of forage normally produced. Local communities have developed traditional methods of water harvesting such as *nadis*, *khadals*, and *tankas*. Such traditional technologies should be used for water-harvesting at as many locations as possible, particularly in grazing lands.

The important cattle breeds, namely Rathi, Nagori, Tharparker, and Kankerj found in the arid region of Rajasthan and breeds of sheep such as Nali, Pugal, Magia, Chokla, Marwari, and Jaisalmer are highly resistant to diseases and could brave the worst that the environment has to offer. Much has been said in the past in favour of upgrading the livestock through cross-breeding with high yielding exotic breeds. Even though cross breeding has often led to improvements in the quality and quantity of the produce by the progeny, unfortunately, in most cases, cross-breeding programmes have stumbled on the rock of adaptability to the desert ecosystem. The cross-breeds cannot, generally (Karakul cross-breeds being perhaps the solitary exception), (1) tolerate the desert heat; (2) forage after long hours under the desert sun on loose sandy soil, as a result of which they remain famished most of the time; (3) go in search of water far away from their night shelters; and (4) tolerate the parasites that crowd the *nadis* or local depressions in the villages, which serve as a source of drinking water for both human and livestock populations (Abichandani and Ghosh 1986).

Such being the experience of the past, it seems prudent to select superior quality animals from among the adapted, indigenous breeds of livestock on the basis of consistent above-average performance in terms of growth rate and

productivity. This approach will not only ensure improvement of livestock but will also help in conservation of genetic diversity of the local livestock population.

Agro-ecosystem

The region has a very limited range of cultivated crops. The main ones grown are pearl millet *(Pennisetum glaucum)*, moth bean *(Vigna aconitifolia)*, and cluster bean *(Cyamopsis tetragonoloba)*, with wheat, barley, oilseeds, vegetables, and fodder crops used to a much smaller extent. Of these, pearl millet is by far the most important.

These crops are grown in an opportunist way and, as the performance of the main crops is almost entirely dependent upon rainfall, yields are low and erratic, especially in the drier areas. As the main crops are food crops, their continued production is essential. However, if it is continued according to the present patterns, which includes cultivation of many unsuitable land types, there will be a further degradation of resources. In the interest of biodiversity conservation, it is necessary that efforts are made to concentrate crop production on more suitable lands, compensating for the smaller areas by adopting improved dry farming technology.

The close ecological interdependence of various vegetation forms in the arid region is epitomized by the fact that under drier conditions, the vegetative phase of herbaceous plants becomes steadily shorter as aridity increases and, as such, plants are found under the shelter of trees and shrubs (Kaul and Ganguli 1963). Combined production system (silvi-pasture, agri-silvi-pasture, and horti-pasture) will enhance the compatibility between existing use and conservation of the components of biodiversity. Review, analysis, and dissemination of available experience on combined production systems is, therefore, urgently called for.

Transfer of water from outside the region, such as the command area of IGNP, has brought about irreversible changes in the habitat of whole biotic communities. In the absence of proper drainage system and efficient irrigation practices, waterlogging and soil salinity have developed. Comprehensive water balance studies are, therefore, necessary to develop efficient water management practices for the IGNP command area. Meanwhile, adoption of conjunctive use of water coupled with bio-drainage, appropriate modification in cropping pattern, and establishment of wind-breaks may provide a suitable approach for management of natural resources of the ecosystem.

The National Commission on Agriculture (NCA 1974) has recommended that cropping pattern in IGNP command areas should include *zaid* and *kharif* fodder crops in 15%, *rabi* fodder in another 14%, and berseem in 1% of irrigated area. Thus, the additional fodder production in this area could be utilized for maintenance and improvement of livestock in the arid region. In addition,

cropped areas would also become available for stubble grazing by sheep after the harvest, where the sheep breeders can migrate temporarily. If such an approach is followed, it would help reduce pressure on the otherwise degraded grazing lands, which could then be improved.

Woodland ecosystem

The extent of the woodland ecosystem is rather restricted. The vegetation is categorized as tropical thorn forest (Champion and Seth 1968), which has a very sparse, low, shrubby vegetation with minor variants in different parts of the topography. Distinctive communities are found on rocky slopes, along drainage lines, sandy plains, and on semi-stabilized sand-dunes. A variety of disclimax communities, or seral communities, are present where the natural vegetation has been disturbed. A large proportion of the species in the vegetation are extremely useful for forage, fuel, small timber, and for medicinal purposes. Many of the prominent species have excellent capacity of regeneration, suggesting that under controlled and wise management, with supplementary enrichment-planting, the woodland ecosystem would improve and enhance its productivity and biodiversity.

Deserts have indigenous species that include plants of medicinal value and NWFP (non-wood forest products), which are put to commercial use. However, adoption of faulty technology, e.g. tapping *Commiphora wightii* for *guggal*, over-exploitation of *Tecomella undulata* for wood carving, of *Citrulus colosynthis* for extracting oil from its seeds for soap-making, and of other medicinal plants has reduced their population. Steps have, therefore, to be taken for their *in situ* and *ex situ* conservation.

Awareness campaign and training programmes

No programmes of conservation of biological diversity could succeed until awareness is created among the local communities of the benefits of conservation. Until they understand why they should safeguard ecosystems, habitats, and species, they will not do so. Non-governmental organizations can play a key role in designing and implementing such awareness campaigns and programmes with a focus on what ecological processes and genetic resources are indispensable and should be conserved as a matter of priority.

Creation of alternative sources of livelihood

In order to release the pressure of population from land, alternative sources of livelihood have to be created in rural areas through development of pisciculture, eco-tourism, and value-addition.

Strengthening of protected areas network

Protected areas are a vital tool for biodiversity conservation. There is an urgent need for establishing PAN (protected areas network), taking into consideration the management and scientific research needs of the region. Our earlier experience has shown that protection of a large number of relatively small areas is valuable in arid regions to reveal what species are present, to provide for seed production, and to demonstrate to local communities the recovery of vegetation once the pressure on the grazing lands in relaxed. However, research should be continued into the question of minimum critical size and optimum distribution of the protected areas required to safeguard a given number and composition of species. The Desert National Park in Jaisalmer needs to be upgraded to the category of a biosphere reserve for providing better protection and management.

PAN and other conservation measures, however, may restrict access to fuel, food, forage, and other products. If substitutes are not provided to compensate for the loss of these resources, the local community is likely to frustrate the protection measures. Compensatory measures such as eco-development of the fringe areas, which *inter alia* include grazing land improvement, raising fuelwood plantations, putting up water-harvesting structures, and supply of fuel-efficient stoves (*chulhas*) as appropriate, are necessary; only then can we succeed in getting the co-operation of the local community for effective protection of such areas.

Building database and monitoring

Even though various aspects of the Thar desert have been well documented, there is lack of baseline data and their evaluation. Immediate steps are, therefore, to be taken for collection of baseline data in selected ecosystems and also in habitats of endemic, exclusive, and endangered species. This has to be followed by a regular programme of monitoring the changes that take place for taking timely corrective measures. This will be possible if the data are transformed or interpreted in a form that makes local community decision-making possible.

Rehabilitation of degraded lands

Revegetation of degraded lands, namely shifting sand-dunes, mine-spoils, and degraded forests should be given high priority.

Legal and policy framework

There are many wide-ranging policies, programmes, and projects, which directly or indirectly serve to protect and conserve the biodiversity of the desert.

Over time, a legal and policy framework has been developed, which relates specifically to biodiversity. On the legal side are the Forest Act, 1927; the Forest (Conservation) Act, 1980; the Wildlife Act, 1972; and the Environment Protection

Act, 1986. These are supported by a number of state laws and statutes concerning forests and other natural resources.

The National Conservation Strategy (NCS 1992) outlines the policy actions required to give greater attention to biodiversity. The National Forest Policy, as amended in 1988, stresses the sustainable use of forests, and the need for greater attention to ecologically fragile (but biologically rich) areas. The National Wildlife Action Plan 1973 lays down the priorities in the area of wildlife conservation.

Even though there is the national policy framework for sustainable use of biological resources, consistent efforts will have to be made on integrating conservation of biodiversity into our planning process to make the operative part of the policy more effective. The most important task is to get a comprehensive assessment of the efficacy of these existing laws made by a group of persons competent in legal matters as well as biodiversity issues for identifying constraints in implementation of laws so that these could be made more effective.

People's participation

Modern scientific knowledge on how the complex, biodiversity-rich ecosystem functions is very inadequate. It is obvious that local communities, with their cultural diversity, have a natural feel for local biodiversity and its range. There is, therefore, a growing realization of the need to motivate people on all aspects of management of natural resources. Such local communities could provide a very critical input to the success of biodiversity conservation if taken as partners in conservation efforts. Thus, there is a need to develop a platform for meaningful interaction between the government and the people as a step towards launching a mass movement in this regard.

It is also necessary to make the local people feel responsible for local-level protection and development activities. One instrument, which has been experimented within the Harda Forest Division in Hoshangabad district in Madhya Pradesh and also through a voluntary agency known as the Society for Hill Resources Management School in Daltonganj in Bihar, is to set up village funds, which are managed by the village communities themselves. Contribution to the village fund is in the form of one day's wages by all the village households, through charging a small fee for taking the fodder produced in common lands or degraded forest areas on a cut-and-carry basis, through charging a small irrigation fee for the use of water from check dams, from sale of the fish produced in village ponds, etc. Experience has shown that the setting up of such village funds provides the much needed relief to the local people in procuring contingent credit requirements such as crop loans at a low rate of interest and frees them from the tyranny of local money lenders. It is also the experience that the villagers hardly default in repayment. The management of the village

fund gives great confidence to the village community in their ability to manage their own affairs. If the village fund is of reasonable size, local level maintenance works as also small structural investments could also be undertaken by the village community itself. This would reduce their dependence on the official apparatus, which is often not prompt in dealing with local requirements. Perhaps, then, the setting up of the village fund could be resorted to more extensively in the interest of involving the local people in managing their affairs and giving them the confidence that they can undertake these responsibilities on their own.

The mainstay of people's participation in Rajasthan has been the panchayat system (CSE 1991). There are, on an average, five villages to a *panchayat*. In the desert area, this number is even greater. It has been seen that in practice, it is far easier for a single village to manage its resource base than to do it in co-operation with a number of villages. Rajasthan has a unique act that gives village communities extraordinary rights to manage their immediate environment. The Rajasthan Gramdan Act of 1971 gives executive and legal powers to the *gramsabha* (village council) to manage the natural resource base within the village boundaries and to penalize those who break its regulations. With the active involvement of non-governmental organizations in accordance with the provisions of the Act, land-use planning by the village community has to be promoted. There is, however, a need for setting up pilot demonstration projects with government funding to operationalize such people's participation models. These projects, besides helping in creating awareness of the benefits of biological resource conservation among the local communities, will also stimulate their participation in biodiversity conservation programme.

Conclusion

The growth in demand for produce from land and livestock is directly linked to human and livestock numbers. The current pressures are due both to ignorance and compulsions of survival. The demands of human and livestock populations on the environment need to be regulated through developing alternative sources of livelihood and the means to meet the needs of the population. Unless a total view is taken of ecological sustainability, the environment will continue to be vulnerable. The short- and long-term objectives of biodiversity conservation and sustainable development are not attainable if we look at the problem from only the technological perspective. The human and behavioural dimensions are equally important as they provide a framework within which change and development take place.

Acknowledgement

I am thankful to Mr O N Kaul and Dr A B Bose for their valuable comments.

References

Abichandani R K and Ghosh P K. 1986
Animal husbandry in the arid zone environment, p. 55-68.
In *Desert Environment Conservation and Management*, edited by Shankaranarayan K A and Shanker V.
Jodhpur: Central Arid Zone Research Institute. 134 pp.

Bhandari M M. 1990
Flora of the Indian Desert, 2nd ed.
Jodhpur: M P S Repros Publishers. 435 pp.

C S E (Centre for Science and Environment). 1991
Environmental problems and institutional capacities in India and select states of India.
Report submitted to the Swedish International Development Agency. 43 pp.

Champion H G and Seth S K. 1968
A Revised Survey of the Forest Types of India
Delhi: Manager of Publications. 404 pp.

Sankhala K S, Bhandari M M, Prakash I, Ghosh P, Melhotra S P. 1988
Thar Desert Biosphere Reserve.
New Delhi: Ministry of Environment and Forests. 100 pp. [Project Document No. 7]

Government of India. 1991
Census of India 1991, Series 1: India. Provisional Population Totals: workers and their *distribution.*
New Delhi: Registrar General and Census Commissioner. 590 pp.

Kaul R N and Ganguli B N. 1963
Fodder potential of *Ziziphus* in the scrub grazing lands of arid zone.
Indian Forester 89: 624–630

Malhotra S P. 1986
Bishnois–their role in conservation of desert ecosystem, p. 23-24
In *Desert Environment Conservation and Management*, edited by Shankaranarayan K A and Shanker V.
Jodhpur: Central Arid Zone Research Institute. 134 pp.

N C A (National Commission on Agriculture). 1974
Interim report on desert development
Delhi: Govt of India Press. 165 pp.

Prakash I. 1974
The ecology of vertebrates of the Indian desert, p. 369-420
In *Biogeography and Ecology in India*, edited by Mani M S
The Hague: Dr W Junk N V. 773 pp.

Annexure 1. List of endangered mammals, birds, and lizards
Source: Sankhala *et al.* 1988

Mammals

Hemiechinus auritus (long-eared desert hedgehog), *Canis lupus* (wolf), *Vulpes vulpes pusilla* (desert fox), *Vulpes bengalensis* (Bengal fox), *Herpestes auropunctatus* (mongoose), *Felis libyca* ornata (desert cat), *Lepus nigricollis dayanus* (desert hare), *Gazella dorcas* (gazelle).

Birds

Adreotis nigriceps (Great Indian Bustard), *Chlamydotic undulata* (houbra), *Cursorius cursor cursor* (desert courser), *Aguila rapax* (tawny eagle), *Aguila clanga* (spotted eagle), *Accipiter spp.* (hawk).

Lizards

Uromastyx hardwickii (spiny-tailed lizard), *Varanus* griseus (desert monitor), *Phyrynocephalus* sp. (toad-headed agama).

■

Summary of possible strategies for conservation of biodiversity in the Rajasthan desert

G S Gujral
British Council Division, British High Commission
17 Kasturba Gandhi Marg, New Delhi - 110 001

The strategies required to safeguard the biodiversity of the area studied during the field visits are shown in Figure 1. It was recognized with some concern that two major species – the Asian lion and cheetah – have already been lost. It is therefore important that the strategies be implemented as soon as possible.

1. The main concern for conservation of biodiversity in the Rajasthan area was agreed to be the human population pressure. The number of people doubled between 1921 and 1961 and increased fourfold between 1961 and 1991.

2. There should be a ceiling on animal numbers. This would not be straightforward as the mix of species, and their temporal dynamics and movement, e.g. due to transhumance, need to be considered.

3. Restrictions are needed on the extent of cultivation, and commensurate with land capability, in such a way that they are acceptable to most local people. This interrelates with fodder production and its distribution.

4. Larger reserves are needed for *in situ* conservation. These do not need to exclude traditional pastoral activities as long as they are carried out at low intensity. In this way, the proposal should be acceptable to most people.

5. A more careful attitude to water-use is needed, especially in urban areas. The arrival of the Indira Gandhi Canal Project and irrigation have changed many people's perception of this commodity, which will be a critical limiting factor.

6. Alternative sources of energy need to be considered. A fuelwood policy for the area needs to incorporate more efficient wood-burning stoves as recommended by the Ministry of Non-conventional Energy Sources, and more extensive use of biogas and LPG (liquefied petroleum gas).

7. Alternative sources of employment are needed to release pressure on the land. These should include the development of tourism, cottage industries, agro-based industries, fish and shrimp production, etc. For example, the Circuit House in Bikaner is a good example of tourist accommodation in urgent need of

restoration to its original high standards; development of value-added products and natural product chemistry, e.g. medicinal plants, is another example.

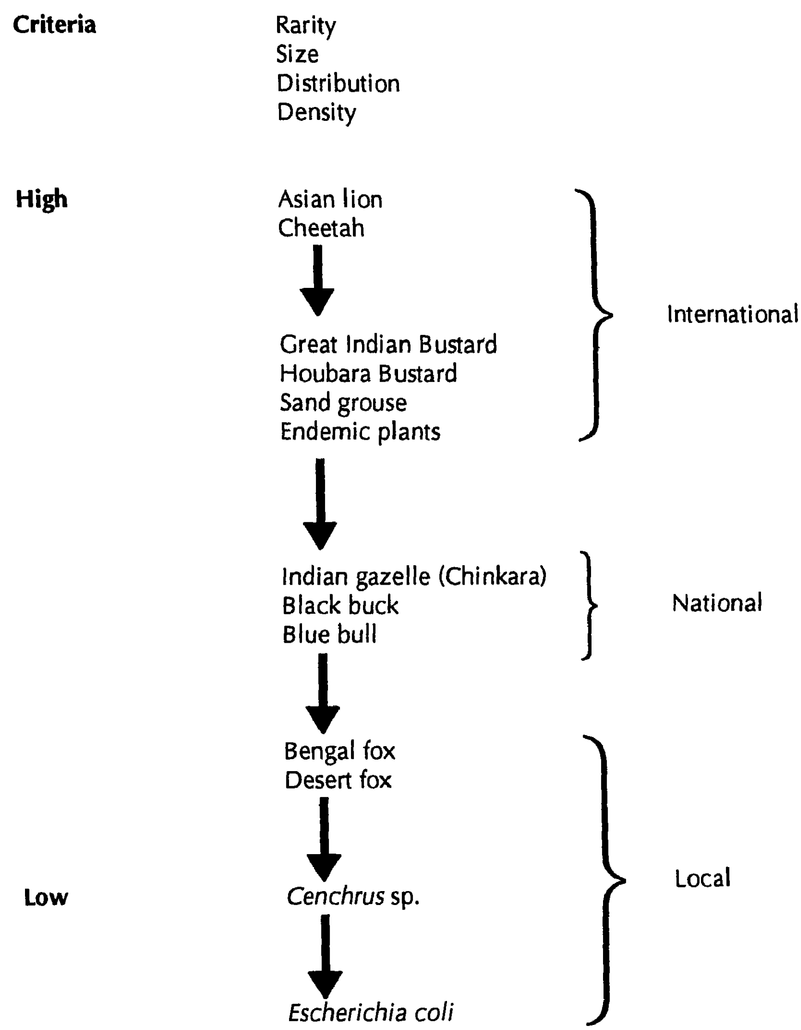


Figure 1. Evaluation of species

8. A policy of education and extension work is needed to engender local support for these recommendations. Much of this work could be carried out by NGOs (non-governmental organizations) but they need to be carefully vetted to ensure that all their policies are acceptable.

9. A policy needs to be developed on mining with stricter regulations on activities that damage, or might damage, biodiversity. If carefully conducted, this may be seen as a positive opportunity for alternative employment.

10. A programme for survey and monitoring needs to be developed. So far, comprehensive lists of species of higher order plants, birds, and mammals are available but very little data suitable for recording future changes. In other words, baseline data for monitoring are lacking.

11. Certain species, usually the rarest, need special attention. *In situ* conservation should be the priority but if this is not possible then *ex situ* measures could be undertaken. This should not be taken as an excuse for the propagation of agronomic plants and the breeding of domestic stock. Those programmes are already under way.

12. Finally, the importance of the protection, development, and expansion of *orans* must not be overlooked. These areas are of religious and ceremonial significance and provide protection to the native species. They now function as centres of dispersal of genetic material, such as the seeds of trees, grasses, and herbs.

13. It was believed that the cost of implementing the scheme should be borne out of the enhanced profitability of the irrigated areas although a precise mechanism to ensure this remains to be spelt out.

A way ahead

Survey and research needs: management for biodiversity conservation

Ronald Kemp
12 Westview Rd, Warlingham, Surrey
Great Britain CR6 9JD

The loss of biodiversity is essentially the result of poor management of natural resources. Because of the pressure from population increase and the needs of socio-economic development, the areas of forest that could be set aside as TPAs (totally protected areas) for the conservation of biodiversity have severe limitations of size, shape, surrounding land-use, isolation, fragmentation of population, and residual influences from past history. Moreover, they are likely to be located in marginal areas, and not representative of the full range of natural habitats. In order to conserve as much as possible of the remaining biodiversity, it is essential to know the composition of biodiversity in each geographical area and to understand how the current nature and levels of diversity are likely to be affected by the limitations of size, shapes, etc. listed above.

A principal objective of survey and research activities must be the collection and interpretation of the data needed for efficient management of biodiversity. In addition to inventories, research is needed into the functional interrelationships and dynamics of the ecosystems as the basis for conservation strategies. These are needed both at the national level, and at various subsidiary levels, culminating in the formulation of management plans for specific areas incorporating biodiversity conservation objectives and the criteria for monitoring their achievement. It is neither necessary nor practicable to attempt to conserve all elements of biodiversity present in every location. Forests are dynamic systems, naturally subject to cyclical change, through successional change, from the colonization of gaps or cleared areas by pioneer species to the mature, old-growth stage. The most species-rich forests are likely to be those that include areas at various stages of successional development.

An important concept in the conservation of biodiversity is the relationship between the 'structural' species, such as the large trees in a forest, and the much larger number of 'interstitial' species (Solbrig 1991) that depend upon them for

many of their basic resources. Together with information on the role of 'keystone' species and 'food web' systems, the information on their interrelationships can be used to guide the management of biodiversity within specific areas, including those subject to sustainable harvesting, such as production forests. Information on patterns of distribution, and on the effects of disturbance caused by harvesting or other management interventions, is needed for strategic planning to conserve biodiversity within an integrated network of reserves, incorporating both TPAs and production forests.

Ultimately, the scientific basis for biodiversity conservation is dependent on the study and interpretation of taxonomic information on genetically determined differences and affinities, their patterns of natural distribution, and the ecological basis for their occurrence. Deviation and interpretation of this information requires the development of databases and GIS (geographical information systems).

Reference

Solbrig O (ed.). 1991
From Genes to Ecosystems: a research agenda for biodiversity.
Paris: International Union of Biological Sciences. 124 pp.

Networking for conservation of biodiversity in India

N K Joshi
Forest Research Institute, Dehra Dun - 248 006

Abstract
India has a network of preservation/protected areas primarily established for *in situ* conservation of flora, associated wild fauna, and studies on dynamics of natural population under undisturbed conditions. These areas are, however, subjected to differing degrees of protection as per the proviso of Indian Forest Act and laws that govern their legal status. Besides, there are many other sites established for *ex situ* conservation of specific plants and animals, i.e. botanical gardens, arboreta, zoological parks and gardens, etc. A networking of the organizations engaged in planning, management, and research in the preservation/protected areas becomes essential in view of the rapid loss of biodiversity and lack of cohesive efforts for their management and dissemination of related information.

Introduction

India is endowed with a wide spectrum of plant genetic resources and is recognized as one of the world's top 12 'mega diversity' nations. The geological history of the subcontinent bestows on the country a range of landscapes and environmental regimes that nurture a wide variety of flora and fauna. The vastness of India's plant genetic resources may be gauged from the fact that 238 families, comprising 16 000 species (nearly 16% of the flowering plants that make up the 425 families recognized to be existing in the world), are known to exist in the Indian subcontinent. Overall, the plant wealth of the country is assessed to be 45 000 species.

India's contribution to the plant species cultivated throughout the world is also significant. It has contributed some very useful plants such as rice, sugarcane, minor millets, brassicas, rice-bean, Asiatic vignas, eggplant, banana, citrus, mango, jackfruit, cardamom, tree-cotton, jute, edible dioscorea, vegetable and seed amaranths, colocacia, black pepper, turmeric, ginger, cucurbits and umbellifers,

Rauwolfia and several herbal drugs, rhododendrons, jasmines, bamboos, ornamental orchids, and aracanut. Some of the biospheres are of vital importance to the country. For instance, the Silent Valley and the adjoining regions have contributed 20 major genes for disease- and pest-resistance used in rice improvement programmes (Khoshoo 1986). The animal wealth of India is over 68 300 species, of which 60 000 are insects, about 1690 are fish, and 370 mammals.

Anthropogenic disturbances in the natural environment, which have caused destruction of plant and animal habitats to varying degrees, result in reversible and irreversible changes in the various ecosystems. Increased developmental activities accelerate these changes. Consequently, nearly 33% of the plant species have become endemic, located mainly in 26 endemic centres in India. The rate of endemism is 33% in reptiles and 62% in amphibians. The *Red Book* published recently lists 814 sensitive species (Nayar and Sastry 1990).

Significant losses of biological diversity could affect the future well-being of human life. Simplification of ecosystems and extinction of species diminish future resource options and the ability of nature to provide life-supporting ecological services. Conservation is an approach that balances people's short- and long-term needs for natural resources through management of lands, workers, and biota to restore, maintain, or enhance basic land-health and productivity. Efforts at conservation are only fruitful with a holistic approach to the peculiarities of an ecosystems's capacity, which demands co-ordination among the organizations engaged in this task. This paper highlights the biodiversity reserves, their monitoring and evaluation, and the possibilities of their networking to enhance the gains and to share the information generated from these endeavours.

Existing scenario

In situ *conservation*

In India, a sufficiently large area has been earmarked for *in situ* conservation of plant and animal life but legal and social controls on the usage of such lands vary greatly and habitats for target species cannot be secured fully. The long-term conservation status of an area is inextricably linked to the protection afforded to it by its legal classification. Biosphere reserves, nature reserves, and sacred forests have no legal status under Indian law.

Floristic reserves

Biosphere reserves

Biosphere reserves are multi-purpose protected areas to preserve the genetic diversity in a given representative ecosystem. As per the recommendations of a

core advisory group set up by the Government of India in 1979, 14 potential sites were identified for setting up biosphere reserves in the country, which are listed below.

Great Nicobar (Andaman and Nicobar Islands)
North Andaman (Andaman and Nicobar Islands)
Namdhapa (Arunachal Pradesh)
Manas (Assam)
Kaziranga (Assam)
Rann of Kachchh (Gujarat)
Kanha (Madhya Pradesh)
Nokrek (Meghalaya)
Thar Desert (Rajasthan)
Gulf of Mannar (Tamil Nadu)
Nilgiri (Tamil Nadu)
Nanda Devi (Uttar Pradesh)
Uttarkhand (Valley of Flowers) (Uttar Pradesh)
Sunderbans (West Bengal)

So far, seven biosphere reserves have been set up, namely Nilgiri (Karnataka, Kerala, and Tamil Nadu), Nanda Devi (Uttar Pradesh), Nokrek (Meghalaya), Great Nicobar (Andaman and Nicobar Islands), Gulf of Mannar (Tamil Nadu), Manas (Assam), and Sunderbans (West Bengal).

Project documentation for the remaining sites has been prepared and is under active consideration of the respective state governments.

Preservation plots

Also termed as miniature nature reserves, preservation plots are demarcated forest areas set aside for the preservation of the forest in perpetuity, permitting only such human interference as necessary for their protection and maintenance.

There are at present 309 preservation plots (Table 1) throughout the country, 187 in natural forests and 122 in plantations, covering an area of about 8500 ha (Khullar 1992). Such permanently protected areas are indispensable to all branches of sciences dealing with natural processes of biological evolution that take place in the particular habitat. In addition, several sample plots have been established in almost all the forest types to study and compare the changes under undisturbed conditions and management systems.

Protected trees

Trees of special botanical interest are protected as long as possible (preferably up to physical age). There are 537 such protected trees in different states of the

Table 1. Preservation plots in India

State	Number of preservation plots: Natural forests	Plantations	Total
Andhra Pradesh	11	—	11
Arunachal Pradesh	1	—	1
Assam	9	1	10
Bihar	9	—	9
Gujarat	18	—	18
Haryana	—	—	0
Himachal Pradesh	6	6	12
Jammu and Kashmir	3	—	3
Karnataka	11	—	11
Kerala	8	43	51
Madhya Pradesh	28	—	28
Maharashtra	11	—	11
Manipur	—	—	0
Meghalaya	2	—	2
Nagaland	—	—	0
Orissa	6	—	6
Punjab	—	—	0
Rajasthan	3	—	3
Tamil Nadu	2	67	69
Uttar Pradesh	32	—	32
West Bengal	27	5	32
TOTAL	187	122	309

Note. None of the Union Territories has a preservation plot.

country. Lists of such trees can be found in Ghosh and Kaul (1977), Bhadran (1958), and Champion and Seth (1968). Details of a few of these trees are given below.

Species	*Locality*	*Girth (cm)*	*Height (m)*
Dipterocarpus gracilis	Andamans	724	43.9
Eucalyptus globulus	Kodaikanal	960	36.6
Michelia champaca	Karnataka	2035	65.5
Pinus roxburghii	Uttar Pradesh	411	65.5
Pterocarpus dalbergioides	Andamans	602	51.5
Shorea robusta	Uttar Pradesh	734	41.4
Tectona grandis	Karnataka	602	25.9

Sacred forest groves

All over the country, a social, cultural, or religious tradition to preserve, protect, and maintain a few patches of forests has existed, which has ensured the conservation of biodiversity to some extent. Some of these forest groves are threatened today in the face of growing population and the changing beliefs of people, particularly the younger generation. Conservation of such groves may now have to be made mandatory.

Closed areas

Closed areas are forest areas where the exercise of rights or privileges such as grazing, felling, grass cutting, collecting minor forest produce, and other activities is prohibited. Such closures may be for silvicultural, punitive, or other reasons. This category may provide some degree of protection to selected species. Closed areas are notified under the Indian Forest Act, and vary in extent.

Reserve forests and protected forests

These are primarily created for the conservation and production of forest resources. However, not being entirely free of encumbrances and access to public, the flora and fauna in them are not fully protected. Moreover, the principal objective of their creation is not the preservation of biodiversity. They may serve as buffer and corridor areas in wildlife sanctuaries and national parks.

Besides the reserve and protected areas discussed above, many wetlands, mangroves, and coral areas have been identified for their conservation (MOEF 1989).

Wetlands

Wetlands are transitional areas between aquatic and terrestrial ecosystems where the water table is wholly at or near the surface of the soil. Wetlands exhibit significant ecological diversity in India, primarily because of variability in climatic conditions and the changing topography.

The National Wetland Management Committee constituted by the Government of India identified 16 wetlands for conservation and management on priority basis. Of these, six have been designated as wetlands of international importance. These are Chilka, Keoladeo Ghana National Park, Harike, Loktak, Sambhar, and Wular. Management action plans for four wetlands, namely Wular, Harike, Kangli, and Renuka are being executed.

Mangroves

Mangroves are salt-tolerant forest ecosystems found mainly in tropical and sub-tropical inter-tidal regions. They sustain rich biodiversity of numerous terrestrial,

arboreal, benthic, and aquatic organisms and provide the source of livelihood for populations in the vicinity.

The total area under mangroves in India is approximately 6700 km^2, comprising about 7% of the world's total mangrove area, and harbours approximately 59 species belonging to 41 genera, of different families. Out of the 15 identified mangroves, action plans have drawn up for five, namely Bhitarkanika, Mahanadi, Sundarban, Goa mangroves, and Achra (Maharashtra).

Corals and coral reefs

Coral reefs can be broadly defined as ridges of limestone, the upper surface of which lies near the sea level and consists of calcium carbonate secreted by the corals. They are known for exceptionally diverse fauna and flora, complex food web, and trophic organisms. Coral reefs in India are limited to Park Bay, Gulf of Mannar, some islands in the Gulf of Kutch, Goa, Lakshadweep, and Andaman and Nicobar Islands. The Government of India has identified following coral areas in the country for their conservation and management: Gulf of Mannar, Gulf of Kutch, Andaman and Nicobar Islands, and Lakshadweep Islands.

Faunistic reserves

The nomenclature of the areas given below is adapted after the Indian Board for Wildlife on national parks (IBW 1970).

National parks. A national park is an area of adequate natural, biological, and geomorphological interest, designated and created by legislation. It is an area owned by the state for the conservation of the scenery, for natural and historic interests of national significance, and for the conservation of wild animals and plants by such means as leave them unimpaired for the enjoyment of the present and future generations. At present, there are 91 national parks in the country.

Wildlife sanctuaries. A sanctuary is an area constituted by the competent authority in which killing and capturing of any form of wildlife is prohibited, except with permission, and the boundaries and character of which are sacrosanct. There are about 510 sanctuaries in the country.

Natural preserves. These are areas of outstanding biodiversity or natural features—human interference is likely to ruin the special features; therefore, entry is allowed only by special permission. Separate nature preserves have not been identified in the country so far. These areas may be either independent or can be parts of national parks, sanctuaries, or other areas, e.g. nesting colonies of birds, large breeding centres of flamingos, congregation of birds, and the inner line of the Himalaya.

Game reserves. These are areas where wild animals are conserved and regulated hunting is permitted.

Other areas. These include areas under the management of government departments other than the forest department or private individuals.

A proposed network of protected areas (national parks and wildlife sanctuaries) suggests increasing the number of national parks to 148 and of wildlife sanctuaries to 503 (Total 651), having an area of 151 342 km^2 (4.6% of India's total geographical area (Rodgers and Panwar 1988). The details of existing and proposed protected areas are given in Table 2.

Table 2. Existing and proposed protected areas in India

	Existing					*Proposed*				
State or Union Territory	*No. of Parks*	*No. of WLS**	*TPA†*	*Area*	*%*	*No. of Parks*	*No. of WLS**	*TPA†*	*Area*	*%*
Andhra Pradesh	0	15	15	9708	3.6	6	25	31	13861	5.1
Arunachal Pradesh	2	4	6	3764	4.5	9	15	24	11187	13.5
Assam	1	5	6	1280	1.6	4	22	26	4820	6.1
Bihar	1	16	17	4692	2.7	5	23	28	3388	3.2
Goa	0	4	4	356	9.4	1	4	5	356	9.4
Gujarat	4	11	15	8608	4.4	8	16	24	7915	4.0
Haryana	0	1	1	1	1	0.0	6	7	220	0.5
Himachal Pradesh	1	28	29	3918	7.0	3	27	30	5412	9.6
Jammu and Kashmir	3	8	11	1897	0.8	7	20	27	12561	5.6
Karnataka	3	15	18	9684	5.0	6	25	31	7424	3.9
Kerala	3	12	15	2308	5.9	5	18	23	3638	9.2
Madhya Pradesh	11	31	42	16592	3.7	13	48	61	21040	4.7
Maharashtra	4	23	27	14895	4.8	12	40	52	9908	3.2
Manipur	1	0	1	40	0.2	3	5	8	1113	5.0
Meghalaya	2	3	5	305	1.4	5	6	11	1,315	5.4
Mizoram	0	0	0	0	0	3	6	9	1555	7.5
Nagaland	0	3	3	71	0.4	1	7	8	340	2.1
Orissa	1	21	22	7710	4.9	4	29	33	9990	6.4
Punjab	0	5	5	244	0.5	1	9	10	338	0.6
Rajasthan	2	23	25	9494	2.8	9	35	44	11633	3.1
Sikkim	1	4	5	965	13.2	2	8	10	2069	28.3
Tamil Nadu	1	9	10	2112	1.6	8	24	32	4410	3.3
Tripura	0	2	2	186	1.8	1	4	5	238	2.3
Uttar Pradesh	4	17	21	7639	2.6	8	30	38	10209	3.5
West Bengal	3	16	19	2438	2.7	4	28	32	2924	3.3
Andaman & Nicobars	6	94	100	710	6.1	17	21	38	2313	25.3
Chandigarh	0	1	1	25	2.5	0	1	1	25	2.5
Delhi	0	1	1	10	0.7	0	1	1	10	0.7
Lakshadweep	0	0	0	0	0	2	0	2	10	5.5
TOTAL	54	372	426	109652	3.3	147	503	651	151342	4.6

*Wetlands, †Total protected areas

Ex situ *conservation*

Various research institutes/universities/states have their botanical gardens, arboreta, zoological parks, etc. Endangered, and also economically and scientifically important, species are reared in these places and may be released to their respective habitats if the species require rehabilitation. The Ministry of Environment and Forests has initiated a new scheme to augment such activities for conservation and propagation of plant genetic resources in different regions of the country by creating a network of botanical gardens and field centres.

Networking

India is a vast country, rich in biodiversity. The natural home of biodiversity is the undisturbed countryside, which is maintained and managed generally by the state forest departments. The forest department, a well-knit organization, has helped in the establishment of protected areas/preservation areas over approximately 5% of India's geographical area, representing almost the entire biodiversity of the country. These areas have been constantly monitored over the years by the forest departments and research institutes and the observations recorded. In the beginning, there was only one research agency, namely the Forest Research Institute, Dehra Dun, that was engaged in forestry research and co-ordinated with state forest departments and other user agencies. Of late, a number of organizations, e.g. ICFRE (Indian Council of Forestry Research and Education) and its institutes, the Botanical Survey of India, the Zoological Survey of India, the Wildlife Institute of India, state forest research institutes/departments, and agricultural and other universities, have been created to contribute to forestry research and forest conservation. These organizations, engaged in research, documentation, and dissemination of information on plant and animal species existing in their respective regions, must collaborate in documenting their findings to draw meaningful results from the information generated by them. Major work on floristic reserves, insects, and micro-fauna is being carried out by ICFRE and its institutes whereas the Wildlife Institute of India is engaged in monitoring the larger animal species and conducting research on their population dynamics in protected areas/wildlife reserves. Similarly, the Botanical Survey and the Zoological Survey also conduct surveys and research related to specific components of the various ecosystems. Only a collective effort can translate information gathered by different agencies into comprehensive knowledge on the various ecosystems.

The major aim of biodiversity conservation is to assist human societies in the sustainable utilization of biological systems and their management. This can only be achieved, firstly, by effectively conserving biodiversity at the national and regional levels and, secondly, by organizing research to understand the subtleties

of ecosystem functioning, species-needs, and interrelations to enable us to comprehend the basics for use in their management. For the purpose, a national network on biodiversity conservation and ecosystem research must be supported by appropriate training, information systems, and a co-ordinating mechanism. The ICFRE has already initiated steps to develop such a network with the support of state and central organizations interested in the work and may serve as a nodal agency for the purpose.

The Forest Research Institute, under ICFRE, at present carries out research in a broad field that contributes to the conservation of biological diversity. This includes documenting and distribution of wild plant species, population biology, landscape ecology, silviculture, entomology, pathology, microbiology, hydrology, resource socio-economics, and inventory and monitoring of ecosystems. These activities are generally conducted in co-operation with state forest departments to address problems related to resource management. This Institute in Dehra Dun is a centre of excellence in forestry research, which constantly monitors most of the protected/preservation areas. Under the umbrella of ICFRE, it has been proposed to set up a national information and library centre. The facilities proposed for this centre on information networking may be gainfully utilized for updating the database on protection/preservation areas and for dissemination of information to other user agencies. The Forest Research Institute thus qualifies to be the networking centre on biodiversity and related fields and seeks the collaboration of other institutions, e.g. the Wildlife Institute of India, the Botanical Survey of India, the Zoological Survey of India, state forest research institutes, and agricultural and traditional universities in this endeavour.

References

Bhadran C A R. 1958
Giant trees of India.
Indian Forester 84(6):

Champion H G and Seth S K. 1968
A Revised Survey of Forest Types of India.
Delhi: Manager of Publications. 404 pp.

Ghosh R C and Kaul O N. 1977
Nature reserves in India.
India Forester 103(8): 498–512

IBW (Indian Board for wildlife). 1970
Wildlife Conservation in India.
New Delhi: Ministry of Agriculture, Govt of India

Kaul O N, Gupta A C, Sharma D C. 1975
Preservation plots in India.
Dehra Dun: Forest Research Institute and Colleges. 44 pp. [India Forestry Bulletin No. 271]

Khoshoo T N. 1986
Environmental Priorities in India and Sustainable Development, p. 96
Calcutta: Indian National Science Congress. 224 pp.

Khullar P. 1992
Conservation of biodiversity in natural forests through preservation plots—a historical perspective.
Indian Forester 118(5): 327–337

MOEF (Government of India). 1989
Wetlands, Mangroves and Biosphere Reserves.
New Delhi: Ministry of Environment and Forests. 269 pp [Proceedings of the Indo-US workshop, 4–7 January 1989, New Delhi]

Nayar N P and Sastry A R K. 1987, 1988, 1990
Red Data Book of Indian Plants, vol. 1–3
Calcutta: Botanical Survey of India.

Rodgers W A. 1991
Forest preservation plots in India—I: management status and value.
Indian Forester 117(6): 425–433

Rodgers W A and Panwar H S. 1988
Planning a wildlife protected areas network in India, vol. 1: the report.
Dehra Dun: Wildlife Institute of India. 341 pp.

Role of voluntary agencies in the conservation of biodiversity

M K Prasad
Kerala Sastra Sahitya Parishad
62 Girinagar, Cochin - 682 020

Conservation is too important to be left to conservationist alone. The daily violence to our life-support systems and natural resource base are acts of men who do not know, or do not care about, the consequences of their actions—or have no alternative to them (de Haes 1986). It must be clearly understood that if the conservation movement is to make headway; if any country's natural heritage and invaluable biodiversity are to be saved; then maximum public support and participation is critical. Voluntary agencies or NGOs (non-governmental organizations) play a vital role in the shaping and implementation of this participation.

When will people come forward to participate? Naturally, the first answer to this question is when people are aware. Awareness can be self-generated or created. Self awareness is related to day-to-day life experience of people and can never come about through academic knowledge. When people become victims of environmental degradation, they naturally develop this perception. But degradation has to manifest itself into more visible effects such as

- scarcity of drinking water
- erosion of the economic base of such scarcity of raw materials
- flood and damage to crops, homes, cattle, etc.
- threat to survival itself

to enable people to think of remedies to their maladies. Then they will come to action, all by themselves. We have a typical example. Garhwal, in the hills of Uttar Pradesh, has a long history of poverty accelerated by increasing population, with consequent destruction of the fuel and fodder resources of villages. Foodgrain production was insufficient and the men-folk of the village were forced to migrate to the plains for employment. The women looked after the farms, livestock, and collection of fuelwood, fodder, and drinking water in addition to their household duties. The floods and landslides, and the consequent

devastation, sharpened everyone's perception of the deteriorating environmental situation and the realization that its major cause was deforestation of the hill-slopes. In 1973–74, the village women started a movement to save their forests. This became known as the *Chipko* movement, which played a significant role in saving the remaining tree cover in reserve forests (Agarwal and Narain 1990). Members of the *Chipko* movement took up afforestation work too. This helped the local communities in many ways. Fuel and fodder shortage was greatly eased.

The Chansar experiment (Shah, unpublished results) symbolizes another unique initiative by the villagers, all by themselves, in a locality that had acquired notoriety for destroying forests. Chansar, in Lunawada *taluka* of Panchamahal district, is a small village of only eighty families. There existed a fairly dense forest, not long ago. It was rich in wildlife and served as a hunting reserve of the local rulers. However, due to deforestation, the area was reduced to bare and eroded hills. The local community, which depended heavily on this forest, was hard-hit. Its economy was undermined.

The village headman explained to the villagers that the cause of their plight lay in the destruction of forests in their neighbourhood and that the remedy lay in their own hands. The villagers resolved that in the name of the Hindu religion, the village forests should be protected at any cost. The community also decided that anyone felling a tree or damaging it in any way will face social boycott in addition to a heavy fine. It was also resolved to appoint a local watchman on a monthly honorarium raised by equal contribution from each household. The experiment was successful. The protected patch recorded excellent growth. This story of success travelled to the adjoining villages and was adopted as a model.

There are some cases where local people, although they had the experience, were incapable of initiating remedial action. The cases of Bankura and Arabari (West Bengal), Kesarpur (Orissa), and Sukhomajiri (Punjab) are examples. Here, the people had to be made to understand what was at stake and how much they owed to natural resources such as forests. There had to be a dialogue about people's needs. Sometimes they had to see something for themselves before they believed it. Sukhomajiri is a typical example. The scientists built a dam, which demonstrated that a reservoir is something people can depend upon when rains fail. These are some instances where people have to be motivated to action even when they have self-generated but latent interest in conservation.

It is difficult to sell the idea of conservation *per se* to the people. Take for example the well-known case of the Silent Valley crusade. It was never a people's struggle to save the Silent Valley, because the local people were not convinced of the worth of conservation, the knowledge of which was out of their day-to-day-life (Prasad 1984). The Silent Valley hydroelectric project was projected as a

symbol of the aspirations of the people of the northern districts of Kerala for a long period and political parties were committed to its implementation long before the ecological questions were raised by environmentalists. The people of the locality were not adversely affected by the project; on the contrary, they stood to benefit from the employment opportunities and income generated by the construction activities. It is true that Silent Valley is one of the richest bioreserves in the whole world, but it is also true that for the people the issues of energy, irrigation, employment, and development were more real, immediate, and obvious than the necessity of protecting the unique biodiversity of Silent Valley. This was the situation to be faced. People were to be mobilized to call for a halt in the implementation of the project. The protagonists of the project were campaigning about the benefits of the project. This is a case where awareness of the significance of conservation had to be generated. Here comes the role of a knowledgeable voluntary agency.

The KSPP (Kerala Sastra Sahitya Parishad) started a mass campaign. Thousands of meetings and marches and hundreds of lectures and seminars were organized. It was a campaign to educate the people about the role of forests in preventing floods and droughts; relationship between forests and rainfall, forests and water cycle, and forests and biodiversity; importance of protecting natural resources for the sustenance of people; etc. In none of the lectures the ecological concepts or the importance of gene pools, or the need to protect endangered fauna and flora, were mentioned directly. The knowledge that everyone acquired through this campaign would have ultimately posed to them a question: 'Should we not protect and preserve Silent Valley then, if we can achieve the same benefits through alternative means?' This example illustrates the role an NGO plays in generating environmental awareness among the people to prepare them to participate in conservation action.

There is a common tendency among policy makers to regard all NGOs as forming a common category of enthusiastic 'do-gooders' who could serve as convenient and cheap labour, or as contentious private groups, or as individuals to be honoured because of their capacity to be troublesome. But Chapter 27 of Agenda 21 (UNCED) points out that NGOs play a vital role in the shaping and implementation of participatory democracy. Their credibility lies in the responsible and constructive role they play in society.

The NGOs concerned with nature conservation may be structured in various ways. They have objectives and programmes that differ widely in the range of their activities, and yet have similar basic concerns. The categories are as follows.

1 Informal groups within educational/research/training institutions. Most members possess some relevant professional qualifications but lack extensive field experience.

2 Youth groups, whose members are from various professional or academic backgrounds but with common interests.

3 Registered nature clubs of younger groups.

4 Professional societies and associations.

There are also a large number of individuals who, without formal affiliation to any particular group, contribute significantly to thought and action that support conservation.

Voluntary agencies can

- share responsibility for observation and collection of information and report periodically to the government at local/regional level;
- act as data banks for workers;
- act as an early warning system for a government agency, which is often far away from the local scene and therefore uninformed;
- take specific research projects based on available expertise; and
- popularize scientific research to help justify it in the public eye.

Rural environmental NGOs work with a series of constraints. First, there is a lack of trained manpower to carry out in-depth technical and economic analysis. Certain individuals from support groups, university departments, and other institutions do help NGOs occasionally but it remains an undependable source of help. Experts working with government departments and institutions, most often, are afraid of working for NGOs. The second constraint is lack of access to authentic data from official sources on projects and programmes with environmental implications. However, the gap is bridged to a certain extent by small volunteer groups seeking the support of NGOs respected within governmental circles or of sympathetic government officials and journalists. The third constraint is the lack of statutory support and judicial sympathy for efforts of NGOs willing to fight against agents of environmental destruction. NGOs should be given statutory recognition in matters such as reports on poaching, illegal felling, pollution etc. so that any court of law can accept their opinions as good evidence.

References

Agarwal A and Narain S. 1990
Strategies for the involvement of the landless and women in afforestation: five case studies in India.
Geneva: International Labour Organisation

de Haes C. 1986
Spreading the message
Conservation with Equity
Gland, Switzerland: International Union for Conservation of Nature

Prasad M K. 1984
Environment and development: KSSP's approach in science as social activism.
Trivandrum, India: Kerala Sastra Sahitya Parishad

Areas of collaboration (Commonwealth aspects)

Ronald Kemp
12 Westview Rd, Warlingham, Surrey
Great Britain CR6 9JD

The forests of the Western Ghats, in terms of the richness of their biodiversity and the severity of the pressures threatening its conservation, typify the situation in many other tropical countries. Although the tropical forests hold by far the greatest part of the global resource of genetic diversity, less than 5% of the tropical forests biome has been set aside for conservation within TPA (totally protected areas) such as national parks or wildlife sanctuaries. Even the most dedicated conservationists now agree that the possibilities for setting aside much larger areas, sufficiently representative of the remaining biodiversity, are already slim, and diminishing, as population pressures continue to rise. The forests reserved for the production of timber or other forest produce are also critically important in biodiversity conservation and can contribute substantially to that objective if they are managed appropriately, on adequate scientific knowledge, within an integrated national strategy, including the TPA system.

Scientific approaches to the natural regeneration and sustainable management of tropical forests for timber production, in concert with the maintenance of the environmental benefits of the forests, were first developed in India. The experience gained was transferred to other countries of the present-day Commonwealth, such as Malaysia, Nigeria, Ghana, and Uganda, around the beginning of the present century. Subsequently, economic pressures to maximize short-term productivity of wood alone tended to replace the diverse natural forests with intensive monocultures. However, the oldest and the best examples of naturally regenerated managed tropical forest are still to be found in the Commonwealth countries.

Despite some differences in forest composition and structure between tropical forests in different regions, the main ecological and developmental processes are essentially similar. The understanding of these processes, and of the effects of disturbance associated with harvesting, provides the scientific basis for silviculture

and forest management, including the deliberate conservation of particular species, communities, or populations in particular areas of forest. Experience has shown that a mosaic of logged and unlogged forest can provide an optimal compromise between the need for productive use of the forest and the conservation of biodiversity. However, further detailed surveys and research in specific areas are needed to develop and refine the understanding of the complex relationships as the basis for new approaches to management to achieve these known objectives.

The remarkable developments in computerized data handling and modelling have already transformed the possibilities for interpreting the large and complex arrays of data involved in such research. However, the gathering of reliable data on forest dynamics, growth, yield, ecological relationships, and responses to disturbance necessarily takes many years to compile and more to test the models derived from survey and research. The knowledge and experience accumulated in the Commonwealth countries over the past 150 years is unparalleled in this respect. In addition to the existing records and observation plots in the forests themselves, it includes the wealth of scientific data and research materials held in research institutes and other scientific centres, including the collections in herbaria and museums throughout the Commonwealth.

With this in mind, a new forestry initiative has been proposed, under the auspices of the Commonwealth Secretariat (Kemp 1992), to develop an international network of selected areas for the demonstration and development of forest management systems, designed to link the conservation of biodiversity with the productive use of the forest. Based on the long known history of forest management in each area, sites will be selected to develop new programmes of integrated research, training, demonstration, and dissemination of knowledge. Each on its own will have considerable value but their total value can be enhanced through the opportunities for scientific exchange of information and experience. The Western Ghats in Karnataka have been chosen as the first site in this proposed international network.

Reference

Kemp R H. 1992.
Commonwealth forestry: a proposed international initiative.
London: Commonwealth Secretariat.

Collaboration to conserve biodiversity

D N Tewari
Indian Council of Forestry Research and Education, Dehra Dun - 248 006

Introduction

Biodiversity is the variety of and variability in plants, animals, and microorganisms on our planet. There are three broad levels of biodiversity: genetic variation within species (and within individual members of that species), the variety of species within a habitat or an ecosystem, and the variety of habitats on the planet.

Information about the characteristics and status of biodiversity is severely lacking for most ecosystems. Any description of biodiversity involves a large and uncertain number of species on the earth. Most of the uncertainty is about the number of species of insects and microorganisms, which account for a large proportion of the total.

Biodiversity has ethical, social, and economic value distinct from that of the biological resources that make it up. Its total economic value is made up of several components, but is extremely difficult to estimate because of the lack of information and uncertainty.

The most important immediate cause of loss of biodiversity is habitat destruction and disturbance. However, it is the complex of underlying socio-economic causes – development pressure, market failure and intervention failure – that is the most significant, and which has to be addressed by any conservation strategy.

There are two basic strategies for genetic conservation: *in situ* (on-site) and ex *situ* (off-site, i.e. in conservation stands, gene banks, arboreta, botanical gardens, etc.). These two strategies are complementary and should be carried out in parallel in case of conservation of species and intra-specific genetic variation. Ecosystem conservation is, by definition, done on-site. However, to be effective in the long term, it must be carried out in parallel with *ex situ* conservation of component species and their genetic variation.

Conservation of biodiversity is necessary to promote sustainable economic and social development and to alleviate poverty in developing countries, where biomass economy is predominant. Specific conservation activities include assistance in biosystematics, exploration of 'hot spot' areas, collection and evaluation of genetic resources, long-term monitoring in ecosystems, the establishment and management of *in situ* and *ex situ* conservation of priority species, etc.

Strategies for genetic conservation

Plant and animal species are becoming extinct or genetically eroded today at an increasing pace, mainly due to loss of natural ecosystems and selection and genetic improvement carried out without adequate concern for genetic conservation issues. Active and vigorous measures are needed to reverse this trend.

Protection or sustainable use of ecosystems can contribute towards the conservation of the genetic variability of component species. However, siting of reserves to reflect intra-specific variation and their management will differ among species. Thus, initial planning must be made at the species and intra-specific levels, subsequently combining the various species networks whenever it is feasible and practicable to do so. In addition to species management, *in situ* conservation will generally require habitat management aimed at protecting existing levels of genetic diversity, and to help maintain co-evolved biological systems that are little known at present.

In situ conservation requires planned and systematic management of clearly identified target species in a network of conservation areas (biosphere reserves, preservation plots, sacred forest groves, national parks, wildlife sanctuaries, nature reserves, etc.) aimed at maintaining the intra-specific genetic variability found in these species. The primary challenge for *in situ* conservation of genetic resources is thus not to select, set aside, and guard protected areas containing genetic resources; rather, it is to maintain genetic variability of target species within a mosaic of economically and socially acceptable land-use options. These may include strictly protected areas, as well as multiple-use reserves, managed forests, and agro-ecosystems.

In the case of *in situ* conservation, it should be recognized that genetic and ecological variations are seldom, if ever, stable; the goal for managers of genetic resources is thus not to preserve a static condition, but to contain a dynamic system. Managed utilization is generally compatible with *in situ* conservation of genetic resources of priority species, provided it is based on basic genetic principles. Similarly, genetic improvement programmes can and should incorporate components of genetic resource conservation; such programmes can even, if well planned, enhance the genetic variation of target species.

It should thus be possible to harmonize the conservation *in situ* of genetic

resources with sustainable use of much of the land area of the country, by including concerns for *in situ* genetic conservation of target plant and animal species as a major component in land-use planning and management strategies.

Ex situ conservation has been used as a major strategy for the safeguarding of genetic resources. At present, valuable material from 'hot spots' is transferred to *ex situ* sites. This strategy is, however, not without problems and should, wherever possible, be complemented by *in situ* conservation strategies for greater security and to enable continued evolution of species.

Status of biodiversity conservation

Some progress has been made in making an inventory of the species in protected areas and mapping species distribution and habitats. However, such efforts have been limited due to lack of

- awareness at the decision-making level of the immediate as well as long-term environmental and economic benefits of conserving genetic resources *in situ;*
- trained personnel and adequate infrastructures at the local/national level;
- identification of priority species and gene pools at local/national and international levels;
- knowledge of intra-specific genetic variability and biology of target species; and
- cross-sectoral co-operation and co-ordination at the local/national and international levels.

Resolving and remedying these shortcomings is a proviso for establishing efficient networks of *in situ* conservation areas.

Basic requirements for establishing conservation networks

Conservation will be greatly facilitated by the development of GIEWS (global information and early warning system) and reports on the subject of the world's genetic resources reported on separately to the Commission. Early development and implementation of the GIEWS is recommended. Awareness of the problems and solutions involved is fundamentally important for success. Continued efforts should be made by the Food and Agriculture Organization and other international agencies to publish and widely disseminate factual information on *in situ* conservation, at decision-making, technical, and grassroots level as well as for the public at large. Immediate action should be taken relating to the following areas.

- Identifying the target species, making use of existing information.
- Validating the distribution data of species chosen through national and international databanks, research centres, and herbaria.

- Collaborating closely with national programmes in defining priority areas for *in situ* conservation for the identified species inside and outside protected areas.
- Drawing up management guidelines based on existing information and research carried out through national institutes and local communities, in support of the conservation and management actions specified.
- Helping in the establishment of a small number of pilot *in situ* networks in each major category, e.g. land races, crop relatives, forest and multipurpose trees, and domestic and wild animals.
- Encouraging assisting countries to strengthen or establish centres for co-ordination of genetic resources activities. In addition to handling matters related to *ex situ* conservation, these centres can focus on *in situ* conservation and the sustainable management of natural and man-made ecosystems so that these continue to provide habitats for priority genetic resources.
- Interacting and sharing information with regional and global data centres concerned with genetic resources. This integration does not exist at present and a mechanism is needed to promote such vertical information exchange.
- Co-ordinating the efforts of various local and national agencies involved in land and natural resource management, coupled with inter-sectoral linkages and collaboration between groups of scientists and technicians as well as NGOs (non-governmental organizations).
- Focusing, at the international level, on raising the awareness of the importance of *in situ* conservation and management of genetic resources; co-ordinating exchange of know-how and experiences of national genetic resources units (which should reflect the work of national governmental and non-governmental organizations in the country); facilitating dialogue between developing countries and the international donor communities; and providing information on regional and global genetic resources priorities.

Conclusion

Local, developing-country, developed-country, regional, and global values and priorities for biodiversity conservation do not always coincide. These qualifications aside, the wider developmental and ethical case for biodiversity conservation remains strong.

There are three reasons why biodiversity is being lost in developing countries at such a dramatic rate despite its value: development pressure, market failure, and intervention failure.

Any strategy for addressing the problem of biodiversity loss must take into consideration the following issues:

- strengthening of existing institutions
- identification of target species
- development of management strategies for priority genetic resources
- international co-ordination and co-operation
- identification of 'hot spots' areas and preparation of detailed inventories of such spots
- preparation of a state-of-knowledge report for each eco-system
- establishing a network by giving nodal responsibilities to the Indian Council of Forestry Research and Education.

Areas of collaboration

A K Ghosh
Zoological Survey of India, Calcutta - 700 053

Introduction

The Indo-British Workshop on Biodiversity provided opportunities for scientists from Britain to interact with their Indian counterparts, first in Calcutta (for wetlands) and then in New Delhi, in February 1993. One of the objectives of the workshop was to identify areas of future collaboration, keeping in view the priorities.

Considering the present status of knowledge on wetland ecosystems and the national policy for conservation and management, a series of areas of research could be identified. The present level of expertise available and the vastness of the area, located in different ecosystems vis-a-vis the rapid changes in land-use pattern in India due to urbanization and other anthropogenic factors, led the scientists to arrive at a set of eleven areas of possible collaboration.

The areas, so identified, vary widely in terms of subject context, proposed areas of investigation, and collaboration.

Classification, survey and management

The first issue under this section will be to formulate an acceptable classification of wetlands in India, keeping in view the international system of IUCN (International Union for Conservation of Nature and National Resources), US-FWS (Fish and Widllife Service), etc. but making it comprehensive on the basis of Indian scenario.

The immediate need, it was agreed upon, is to evolve an RSM (rapid survey methodology) for identification of wetlands for priority attention (for conservation and management practices). While some basic data have been published by the Ministry of Environment and Forests, Government of India, detailed survey data are lacking. Even if remote-sensing techniques are used, ground-truth verification can only be achieved by using an applicable RSM.

Since the Government of India has already identified 16 wetlands of national importance in different regions of the country (of which 5 are Ramsar sites), it is imperative to have well-formulated management plans for each of these wetlands. Considering the quantum of work involved, a priority list has also been suggested for Phase 1 of the programme, keeping in view the use and functional aspects and sociological aspects of four wetland areas (recommended under Phase 1).

Research, investigation and preparing manuals

Research needs, based on topographical location and climate zone, especially in the arid and semi-arid regions, high mountains, and Gangetic plains, were emphasized.

The Indian wetlands often face a crisis due to soil erosion and siltation. The need to evolve a suitable method for silt control, which may be used for managing silt-prone wetlands, was stressed by a number of participating scientists.

The other aspects of research will aim at evolving an integrated approach for vegetation, soil, hydrology, and biological aspects of the threatened species of biota, specially benthics.

At present, no comprehensive keys are available to identify major wetland fauna and flora in India. While such keys are to be for both field identification and use in the laboratory, they can only be prepared on the basis of actual field collection, past research data, and further investigation. The preparation of field key being an immediate necessity, the work should be accorded priority.

Training

The areas of collaboration have also been identified in training components, involving field survey and research methodologies with regard to Item 2 and Item 9 of Annexure 1.

Besides such training to develop manpower for quick evaluation of wetlands, training in taxonomic studies of selected groups of vegetation and aquatic fauna is considered vital. Details of such groups of aquatic flora and fauna will be worked out in subsequent meetings.

The application of GIS (geographical information systems) needs mathematical modelling in wetland management and conservation as has been done in Britain and it was pointed out that training in this area may be of immense value in the Indian context.

Database on Indian wetlands

At present, no database is available on Indian wetlands, mangroves, and coral reef except for one printed directory (based on information submitted by state

governments) on wetlands. It is strongly felt that such a database can be established with available information, with a facility to add data (on-line system) as the work progresses on field survey. The details of parameters are to be evolved, keeping in view the variability of wetlands in terms of geographical location, use-classification, and biological resources.

Periodical meetings and workshops at national level, under the aegis of the Ministry of Environment and Forests, involving central survey organizations, regional universities, agriculture, irrigation, fishery departments, and NGOs (non-governmental organization) are recommended for effective interlinking and to avoid possible duplication of work. The recommendations arising out of the meetings can be of much value to the National Committee on Wetlands, Mangrove and Coral Reef. This can be supplemented by meetings of select experts in India and in Britain. The Annexure that follows provides a list of recommendations.

Annexure 1. Areas of co-operation: wetlands ecosystems

1 Developing a classification of wetlands based on the Indian scenario.

2 Evolving a rapid survey methodology for wetlands (excluding the 16 national wetlands) in the Indo-Gangetic and upland areas of India, using biological indicators.

3 Evolving an integrated management plan with emphasis on conservation of biodiversity in selected wetlands [e.g. Chilka (Orissa), Kabar (Bihar), Loktak (Manipur), and peri-urban wetlands of East Calcutta (West Bengal)], which are under great stress from anthropogenic and other factors.

4 Finding out the possibility of the application of GIS and mathematical modelling in selected wetland ecosystems (e.g. Chilka, Kolleru, and Pulicut) for the conservation of biodiversity.

5 Co-ordinating research in selected wetlands based on topographical location and climate zones.

6 Finding out most suitable methods of silt control in heavily silt-prone areas of wetlands.

7 Conducting research in population biology of races/threatened species of biota (specially benthos).

8 Preparing field identification keys, based on collaborative work in taxonomy.

9 Training in survey and research methodologies involving the basic parameters of hydrology, soil, vegetation, fauna, and socio-economics.

10 Training in taxonomic studies of vegetation and selected aquatic faunal groups in view of the lack of adequate expertise vis-a-vis needs.

11 Devising ways to interlink the efforts of (1) Central Survey Organization,

(2) regional universities (identified by the Ministry of Environment and Forests), (3) other universities, research institutes, (4) state governments, and (5) NGOs to create an effective database for each of the 16 national wetlands and 15 mangrove ecosystems and to avoid duplication of work. Location-specific workshops (such as those for Sundarbans, Chilka, and Kolleru held in the 1980s) could help bring together all workers.

To negotiate the details of these possible areas of collaboration, a dialogue is needed between the Indian and the British side, subject to approval from the two Governments.

Potential conservation strategies for wetlands in India

C Newbold
Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough
Great Britain PE1 1JY

Abstract

Three overall strategies need to be considered if wetland biodiversity is to be conserved. First, catchment-use should be compatible with conserving the natural biodiversity of a wetland. Second, the traditional use made of a wetland should be sustainable. And essential to these two is improving attitudes and awareness. These there themes suggest specific needs and directions for research and field action programmes on wetlands, which include the following.

- Basic survey and selected areas of fundamental research.
- Applied research needs—specifically, assessing, quantifying, and monitoring water quantity, quality, hydrology, and sustainable use.
- Integrating wetlands management with catchment-use. Only some aspects are selected for discussion, namely sediment management, water quantity, water quality, and fishery management.
- Managing coastal wetlands as natural features for coastal defence.
- Education and training of wetland conservationists, managers, and the general public.
- Improving wetland policies and legislation, particularly for international rivers.
- Advising and assisting development banks and aid agencies.

Introduction

Wetlands are defined as those wet areas, permanent or temporary, standing or flowing, fresh or brackish, and embracing saltwater systems down to a depth of 6 metres.

This is the Ramsar definition upon which many sites are protected against degradation or loss of biodiversity if the member state is a signatory to that convention. Wetlands, by definition, cover a range of habitats from lake, fen,

marsh, mire, river, coastal lagoons, mangrove systems, and estuaries.

A wetland may perform one or more functions, depending on catchment-use and catchment characteristics. These functions, some which may lower natural diversity, are

- groundwater recharge
- groundwater discharge
- flood storage and desynchronization
- shoreline stabilization
- reduction in erosion, using wetland vegetation
- sediment trapping
- nutrient retention or removal
- food chain support
- fish habitat
- wildlife habitat
- active and passive forms of recreation
- heritage value.

All wetlands are affected by catchment area use. They are influenced by factors such as the hydrology of the area, the retention times of surface water, and nutrients, sediments, and pollution loads.

One of the important factors in conserving a wetland's natural biodiversity is to achieve a catchments-use that is compatible with the wetland. Anthropogenic activities such as afforestation, deforestation, agriculture, industry, mining, and urban settlements result in altered flows of water, nutrient, and sediment; pollution loads; and a changed – often lower – level of biodiversity.

Some forms of traditional use may modify, but still help sustain, a high level of biodiversity. Such modified or semi-natural biodiversity is still important and most wetlands in India and the United Kingdom have been affected in this way.

In some cases, wetlands may have been created by human actions and management; in others, human societies have evolved in close association with wetlands (Gopal 1991).

The role of human activities in the maintenance or disruption of the biodiversity of different wetlands needs to be evaluated.

Wetland values, their functions, and the importance of biodiversity has to be communicated to all those involved in traditional use, those using the area for recreational use, relevant managers, and politicians.

An extensive programme of training and education is necessary for improving attitudes and awareness.

Strategic directions

The four main strategic directions for any nation wishing to maintain or enhance its natural biodiversity are the need to

- stabilize population growth
- decrease demands on wetlands resources to the level of sustainable use
- manage catchments in ways that are compatible with conserving wetland biodiversity
- improve attitudes and awareness.

Specific needs and directions

Specific needs and directions in any field action programme for wetlands could be the following.

- Basic survey and selected areas of fundamental research.
- Assessing, quantifying, and monitoring water management approaches. These components are water quantity and water quality, both surface and groundwater.
- Integrating wetland management with catchment-use. Those aspects of management considered in this paper are sediment management, water and fishery management, integrated catchment management plans, and managing coastal wetlands as natural features for coastal defence against flooding events. (This will be particularly important if there is a major change in climate or if sea levels begin to rise.)
- Education and training of wetland conservationists, managers, and the general public.
- Improving wetland policies and legislation particularly for international rivers.
- Advising and assisting development banks and aid agencies.

These last two specific needs, whilst essential to an overall strategy, are not considered in detail in this paper.

Research and survey

Research and survey needs have been discussed in detail in a previous paper (Newbold, pages 52 to 65 in this volume). In summary, fundamental or basic research is seen as a means of understanding ecosystem functioning. Energy flows, nutrient dynamics, and interaction between species throughout a food web are just a few important examples. Applied research helps answer specific needs—the importance of nutrient budgets, sediment transport, and hydrology are considered in detail in later sections of this paper.

Table 1. Survey priorites in the British Isles. Wildlife components and physico-chemical components used to assess the status of wetland sites and criteria for assessment (after Ratcliffe 1977)

Wildlife components	*Physico-chemical components*	*Assessment criteria*
Birds	Depth (if lake)	Size
Mammals	Water chemistry (including hardness)	Diversity (habitat and species)
Macrophytes or wetland plants	Sediment type	Naturalness
	Geology	Rarity
Algae	Hydrology	Fragility
Invertebrates	Salimity gradient in brackish systems	Typicalness
Amphibia	Macrotope (if mire system)	Position in ecological/ geographical unit
Reptiles	Hydromorphology (if mire system)	
Fish	Mesotope (mire margin mire expanse)	Potential value
	Microtope (surface patterns of mires)	Intrinsic appeal (landscape value)
	Microforms (in mire systems)	Position in catchment

Survey needs are also important. There seems to be a need for a comprehensive and ordered typing and assessment of wetlands, producing a wetland inventory for India. This would need to categorize wetlands according to ecosystem type (e.g. oligotrophic, mesotrophic, or eutrophic lake), an assessment of its biodiversity, and the relative value of that interest in terms of regional, national, or international importance. The philosophy and criteria used in Britain are well documented (Ratcliffe 1977).

Assessing, quantifying, and monitoring water uses

Hydrology

Field action programmes need to consider the hydrology of a wetland and how catchment use will affect the water regime. Hydrological studies may need to consider both groundwater and surface water use. The interaction between groundwater and surface water and salinity gradients in brackish water lagoons is particularly relevant for Chilka lake, Orissa. A mobile coastal sand bar is beginning to block up the outflow, which could increase the freshwater component of the lake. Many of the fish species are dependent on brackish conditions and the fishery industry could decline in the short term as the fish fauna adopts to the changing conditions. If the lake's salinity gradient is to be preserved, a quantitative estimate of sea water inflows is necessary. This then dictates the size of a newly dredged inflow point. Its position along the sand bar will have to be determined by an accurate hydrological assessment of saltwater inflows and freshwater outflows against the desired salinity gradient.

Nutrient budgets

Eutrophication or enrichment due to excess nutrients, particularly nitrogen and phosphorus, seems to be as prevalent in India as it is in the United Kingdom. Eutrophication is caused by urban sewage and agricultural fertilizer use and is a feature of countries of high population densities and intensive or extensive agriculture. Eutrophication in its early stages normally increases aquatic macrophyte production, which increases food web production and fish production. Fishermen, however, may find the weed-free area for fishing reduced. If eutrophication processes are allowed to advance unchecked, aquatic macrophyte production will suddenly collapse—to be replaced by algal production (Phillips, Eminson, Mass 1978). Fishery production will also collapse. A balance in the eutrophication process should be sought not only for biodiversity but also for socio-economic reasons.

A quantitative assessment of nutrient sources, leading to a nutrient budget for a wetland, may be necessary to understand and prioritize inputs for remedial treatment. A nutrient budget not only identifies the sources of nutrients, such as agriculture or urban sewage, but also partitions the catchment, giving loading figures for uses in segments of the catchment.

Sediment loadings

Essential to any nutrient budget would be an assessment of sediment loadings.

Agricultural use of the catchment for arable crops such as rice or wheat and deforestation due to a variety of needs eliminate the binding effect of tree and grass roots. Heavy rains during the monsoon erode the bare soil. Lakes are one of the depositing areas for this silt. Such systems carrying out this function of sediment accretion have a shortened life span, hastening the natural seral progression to dry land. Whilst the loss of the lake or a part of it will affect traditional wetland use, such as fishing, nursery areas for fish, or the use of aquatic plants for cattle feed, of equal or greater concern should be the loss of valuable soil and the long-term fertility of the catchment.

The main inflow to Chilka lake, Orissa, is accreting at a rapid rate, presumably due to changes in catchment area use. Aquatic plant production is also increasing, presumably due to local eutrophication. Fishermen complain of the rapid growth of aquatic plants on these sediments, which reduces the area available for fishing. (C R Das, personal communication 1993). The aquatic plants, however, are collected for cattle feed and are a valuable nursery area for fish.

Field action programmes for Chilka lake ideally involve a hydrological study, a sediment and nutrient budget to assess the relative importance of catchment inputs, and a socio-economic study. Management solutions to the identified problems will then have to be agreed upon by the local people. Chilka lake may

well be one example typical of the conflicting interests and uses of many wetlands in India.

Integrating wetland management with catchment use

Urban sewage, industrial pollutants, agricultural pollution from fertilizers and pesticides, and sediment loadings all impinge on – if not affect the use, production, and quality of – the goods and services offered by a wetland.

Catchment area use should be integrated with the traditional use made of a wetland. Equally traditional uses should be sustainable and not exploit the wetland resource.

Sediment management

Soil erosion within the catchment loses a valuable resource which accretes within a wetland. Soil conservation measures within the catchment should be a priority action programme. Re-afforestation schemes, and a field-by-field series of bunds, particularly where the run-off feeds the first-, second-, and third-order streams, will help prevent erosion. The bunds should be designed to contain the peak rainfall events during the monsoon, and water could be released slowly after the silt settles down. Sluices would have to be constructed within the bunds. The key is to contain rainfall in a series of small field 'washlands' before the cumulative effect of water from several thousand fields creates an uncontrolled flood. Sediments are trapped within a field rather than by a receiving body such a wetland. This leads onto another theme, namely water management.

Water management

Water is a precious resource, yet much of the monsoon rain flows unused out to the sea. A series of large-scale 'washlands' or artificial wetlands by major rivers could be constructed to store some of this water. This would be used solely for irrigation. The washlands, as they are drawn down, might still be used for a late crop of rice. They would also fulfil the dual wetland functions of flood storage and desynchronization of flows.

Industrial pollution and the Calcutta wetlands

The Calcutta wetlands are a highly modified former mangrove area, a series of extensive settlement lagoons used to naturally treat the sewage effluent from that city (Ghosh and Sen 1987). Although they have lost many wetland species, the modified wetland still contains some wetland biodiversity (Ghosh and Chattopadhyay 1982). Of importance is its secondary use as a fishery and, for the tertiary lagoons, their value as recreational areas.

Fish production is a valuable source of income and protein for the people

of Calcutta. At present, industrial pollutants are not separated from human sewage and concern must be expressed at, for example, the heavy metal burdens found in fish. If possible, factory effluents could be targeted for treatment using calcium oxide (Albright and Wilson 1992). A field action programme could be to use this method at other industrial complexes throughout India.

Fishery management

Traditional sustainable use of the fishery resource within a wetland is moving to one of over-exploitation in many areas of the world. As the human population increases so the demand increases. Short-term gain to supply the need is sacrificing the long-term survival of the fishery. Chilka lake has experienced a reduction in catches over a ten-year period from 10 000 tonnes to 6000 tonnes/annum (C R Das, personal communication 1993). This is a loss in productivity from 86 kg/ha to 52 kg/ha. Small-scale village pond fish production is more than possible but rarely practised in India. In China, a series of small village ponds culture Cyprinid fish species in highly fertilized water. They use animal manure and human sewage. In the second year, algae are so abundant that duck are introduced to graze the algae. In the third or fourth year, the pond is drained and the sediments spread in the field as manure. The pond is then re-filled and the cycle repeated. A similar strategy in villages throughout India would provide valuable protein, give a more varied diet, and take the pressure off wetland fisheries. Such fisheries could then be managed in a sustainable manner.

The use of animal manure and human sewage also cumulatively reduces loadings on a wetland, thereby reducing potentially the damaging eutrophication processes.

Integrated planning and catchment management programmes

Applied research needs – assessing, quantifying, and monitoring water-uses explain some of the processes from which management decisions can be made.

Successful wetland management is linked to a sustainable non-exploitative use of its own resources. Catchment-use also affects a wetland. Catchment-use can be so planned and managed that a wetland's internal functions and production are not impaired. Nutrient and sediment budgets, if properly constructed, can target priority areas for such remedial management. Such a strategy is one base on which integrated catchment planning and management programmes are founded. Other strategies should target industrial pollution sources and urban planning. Socio-economic appraisals such as that researched by Kar (1993) for the immediate catchment area of Bhitarkanika, Orissa, a nationally important wetland, are crucial planning and management studies. Such appraisals help in the integrated planning and management of catchments.

Managing coastal wetlands as natural features for coastal defence

Saltmarsh in Great Britain is now considered to be a valuable wetland resource. It serves as the first line of coastal defence against flooding by absorbing wave energy. Mangrove systems in India fulfil the same function. Bhitarkanika, Orissa, is a nationally important wetland reserve for mangrove. Human population pressure and the need for wood as a building material have resulted in large-scale destruction of mangrove. Das (1993) has indicated the need for financial assistance for the restoration of mangroves serving the dual function of habitat restoration and sea defence. He also stresses the development of agro-forestry as an alternative means of supplying the people's needs.

Importantly, the public needs to be made aware of the value of mangrove in providing that essential line of sea defence through an educational programme.

Conclusions

Field action programmes and research needs for conserving the biodiversity of a wetland must consider the human use made of both the resources within a wetland and those external to it, i.e. the catchment.

Water quantity, water quality, and hydrology are seen as essential components in catchment use and wetland performance. A quantitative assessment of these factors in the form of nutrient and sediment budgets, hydrological studies, and the monitoring of these is seen as essential before informed management decisions can be made. The next important step is the integration of wetland management with catchment-use. Sediment management, water management, fishery management, and socio-economic studies are all components of integrated planning and management programmes.

Education and awareness programmes are also seen as essential. To this end, another field action programme is the awareness of, and the restoration of, mangrove as a first line of coastal defence. Other considerations are the diversification of agriculture into agro-forestry schemes and fish culture and the use of constructed washlands to supply irrigation water. The theme is one of an alternative self sufficient agriculture so as to reduce the internal exploitative pressures on the resource use of a wetland. In this way, a sustainable use of a wetland might be achieved, thereby maintaining its biodiversity and its heritage value.

References

Albright and Wilson. 1992
Protecting the Irish Sea.
Whitehaven, Cumbria (UK): Albright & Wilson Ltd.

Ghosh A K and Chattopadhyay S. 1982
Biological resources of Brace Bridge wetlands, p. 189–206
Zoological Survey of India

Ghosh D and Sen S. 1987
Ecological history of Calcutta's wetland conservation.
Environmental Conservation 14(3): 219–226

Gopal B. 1991
Wetlands and sustainable development, p. 63–67
In *Ecology and Sustainable Development*, edited by Gopal B.
New Delhi: National Institute of Ecology

Kar K. 1993
Participatory rural appraisal for understanding the man: environment conflict and its impact on the loss of biodiversity of wetlands ecosystem at Bhitarkanika mangrove area in Orissa.
(REM/93/006/kar)

Phillips G L, Eminson D, Moss B. 1978
A mechanism to account for macrophyte decline in progressively eutrophicated freshwaters.
Aquatic Botany 4: 103–126

Ratcliffe D A. 1977
The Nature Conservation Review, vol. 1 and 2
Cambridge: Cambridge University Press

Participants

List of participants

Dr S A H Abidi
Department of Ocean Development
Mahasagar Bhawan
C G O Complex
Block No. 12, Lodhi Road
New Delhi - 110 003

Dr I P Abrol
Indian Council of Agricultural Research
Krishi Bhawan
Dr Rajendra Prasad Road
New Delhi - 110 001

Mr A Agarwal
Centre for Science and Environment
F-6 Kailash Colony
New Delhi - 110 048

Mr H Agarwal
Indian Science Writers Association
D-40 Gulmohar Park
New Delhi - 110 049

Dr Ruth Alsop
Ford Foundation
55 Lodhi Estate
New Delhi - 110 003

Mr R K Anthwal
National Research Development Corporation
Anusandhan Vikas
20–22 Zamroodpur Community Centre
Kailash Colony Extn
New Delhi - 110 048

Dr (Mrs) S Arora
Ministry of Environment and Forests
Paryavaran Bhawan
C G O Complex
Lodhi Road
New Delhi - 110 003

Prof. C R Babu
Dept of Botany
University of Delhi
Delhi - 110 007

Mr P Bagla
Publications and Information Directorate
Council of Scientific and Industrial Research
Dr K S Krishnan Marg
New Delhi - 110 012

Mr J Bahadur
Ministry of Science and Technology
Technology Bhavan
New Mehrauli Road
New Delhi - 110 016

Dr D K Banerjee
School of Environmental Sciences
Jawaharlal Nehru University
JNU Campus
New Delhi - 110 067

Ms Aditi Banerjee
British High Commission
Chanakyapuri
New Delhi - 110 021

Ms Seema Bhatt
World Wide Fund for Nature
WWF India Secretariat
172 B Lodhi Estate
New Delhi - 110 024

Mr A Bhattacharya
United Nations Development Programme
55 Lodhi Estate
New Delhi - 110 003

Dr A K Bhattacharya
School of Environmental Sciences
Jawaharlal Nehru University
New Mehrauli Road
New Delhi - 110 067

Dr D K Biswas
Ministry of Environment and Forests
Paryavaran Bhawan
C G O Complex, Lodhi Road
New Delhi - 110 003

Mr Ove Bjerregaard
United Nations Development Programme
55 Lodhi Estate
P O Box 3059
New Delhi - 110 003

Dr A Chaudhary
Dept of Marine Sciences
Calcutta University
Calcutta - 700 073

Mr K P S Chauhan
Ministry of Environment and Forests
Paryavaran Bhawan
C G O Complex
Lodhi Road
New Delhi - 110 003

Mr S Chinnamani
Indian Council of Agricultural Research
Ministry of Agriculture
Krishi Bhawan
New Delhi - 110 001

Prof. V L Chopra
Indian Council of Agricultural Research
Krishi Bhawan
New Delhi - 110 001

Mr C Clift
British High Commission
Chanakyapuri
New Delhi - 110 021

Mr H Dang
Sustainable Development
B-17 Ansal Chambers-1
New Delhi - 110 066

Prof. P K Das
Department of Ocean Development
Mahasagar Bhawan, Block 12
C G O Complex, Lodhi Road
New Delhi - 110 003

Mr R Datta
British High Commission
Chanakyapuri
New Delhi - 110 021

Dr J Davies
Asian Wetlands Bureau
Institute of Advanced Studies
University of Malaya
Lembah Pandai
59100 Kuala Lampur, Malaysia

Dr S C Deorani
Indian Council of Forestry Research and Education
Dehra Dun - 248 006

Dr Deshbandhu
Indian Environmental Society
U-112 (3rd floor)
Vidhata House, Vikas Marg
New Delhi - 110 092

Mr K Desiraju
Ministry of Environment and Forests
Paryavaran Bhawan
C G O Complex, Lodhi Road
New Delhi - 110 003

Mr E Dessau
United Nations Development Programme
55 Lodhi Estate
New Delhi - 110 003

Mr S C Dey
Ministry of Environment and Forests
Paryavaran Bhawan
C G O Complex, Lodhi Road
New Delhi - 110 003

Dr P Farooqui
Department of Science and Technology
New Delhi - 110 016

Prof. M Gadgil
Centre for Ecological Sciences
Indian Institute of Science
Bangalore - 560 012

Mr A Ghosh
Annexe 5, Bikaner House
Shah Jahan Road
New Delhi - 110 011

Dr Barry Goldsmith
Dept of Biology
University College
Gower Street
London WC1E 6BT

Mr B Gopal
School Of Environmental Studies
Jawaharlal Nehru University
New Delhi - 110 067

Dr Ian Gould
Dept of Entomology
British Museum (Natural History)
Cromwell Road
London SW7 5BD

Dr P K Hajra
Ministry Of Environment
and Forests
Paryavaran Bhawan
C G O Complex, Lodhi Road
New Delhi - 110 003

Dr E Hanley
Forestry Field Management
Office
British High Commission
Chanakyapuri
New Delhi - 110 021

Dr Alan Hildrew
Professor of Ecology
Queen Mary College
Mile End Road
London E1 4NS

Mr J Holmes
British High Commission
Chanakyapuri
New Delhi - 110 021

Dr S A Hussain
Asian Wetlands Bureau
Institute of Advanced Studies
University of Malaya,
Lembah Pardai
591000 Kuala Lumpur
Malaysia

Mrs Malti Jaikumar
British High Commission
Chanakyapuri
New Delhi - 110 021

Mr N D Jayal
INTACH
71 Lodhi Estate
New Delhi - 110 003

Mr Yateendra Joshi
Tata Energy Research Institute
9 Jor Bagh
New Delhi - 110 003

Mr A K Kanchan
British High Commission
Chanakyapuri
New Delhi - 110 021

Mr R Kapoor
Standard Chartered Bank
17 Sansad Marg
New Delhi - 110 001

Dr S Kaul
Ministry of Environment
and Forests
Paryavaran Bhawan
C G O Complex, Lodhi Road
New Delhi - 110 003

Mr R N Kaul
National Afforestation and
Ecodevelopment Board
Ministry of Environment
and Forests
Paryavaran Bhawan
C G O Complex, Lodhi Road
New Delhi - 110 003

Mr R Kemp
UK Tropical Forest Forum
12 Westview Road
Warlingham
Surrey
Great Britain CR6 9JD

Mr Irshad Khan
Ministry of Environment
and Forest
Paryavaran Bhawan
C G O Complex, Lodhi Road
New Delhi 110 003

Mr A K Khare
Society for Promotion of
Wastelands Development
Shriram Bharatiya Kala
Kendra Bldg
1 Copernicus Marg
New Delhi - 110 001

Dr A Khosla
Development Alternatives
Qutab Institutional Area
New Delhi - 110 016

Mr A Kothari
Indian Institute of Public
Administration
Indraprastha Estate
New Delhi - 110 002

Dr Suresh Kumar
Central Arid Zone Research
Institute
Jodhpur - 342 003

Dr D Lahiry
National Council of
Educational Research and
Training
Sri Aurobindo Marg
New Delhi - 110 016

Dr G Lucas
Royal Botanic Gardens
Kew, Richmond
Surrey
Great Britain TW9 3AB

Prof. John MacArthur
Development and Project
Planning Centre
University of Bradford
Bradford
Great Britain BD7 1DP

Mr A V S Manium
Development Section
British High Commission
Chanakyapuri
New Delhi - 110 021

Dr S Mauria
Indian Council of Agricultural Research
Krishi Bhawan
New Delhi - 110 001

Dr Y Medury
Educational Cunsultants India Ltd
C-24 Friends Colony
Mathura Road
New Delhi - 110 065

Mr G S Mudur
Press Trust of India
PTI Building (1st floor)
4 Parliament Street
New Delhi - 110 001

Prof. K G Mukherjee
Department of Botany
University of Delhi
Delhi - 110 007

Mr I Napier
Forestry Management Office
British High Commission
Chanakyapuri
New Delhi - 110 021

Dr Chris Newbold
Joint Nature Conservation Committee
Monkstone House, City Road
Peterborough
Great Britain PE1 IJY

Mr S Parameshwarapa
Karnataka State Forest Department
Aranya Bhawan
Bangalore - 560 003

Mr A Patni
British High Commission
Chanakyapuri
New Delhi - 110 021

Dr S Z Qasim
Planning Commission
Yojana Bhavan, Sansad Marg
New Delhi - 110 001

Dr S N Rai
Conservator of Forests and Research, Malleswaram
Bangalore - 560 003

Mr R Rajamani
Ministry of Environment and Forests
Paryavaran Bhawan
C G O Complex, Lodhi Road
New Delhi - 110 003

Prof. P S Ramakrishna
School Of Environmental Studies
Jawaharlal Nehru University
New Delhi - 110 067

Dr R S Rana
National Bureau of Plant Genetic Resources
Pusa Campus
New Delhi - 110 012

Prof. N S Randhawa
EA-220 Maya Enclave
New Delhi - 110 064

Mr Ajay Rastogi
World Wide Fund for Nature
WWF India Secretariat
172 B Lodhi Estate
New Delhi - 110 024

Mr R D Rikhari
National Research Development Corporation
Anusandhan Vikas
20-22 Zamroodpur Community Centre
Kailash Colony Extn
New Delhi - 110 048

Ms R D Roy
World Wide Fund for Nature - India
India Secretariat
172 B Lodhi Estate
New Delhi - 110 024

Dr C J Saldhana
Centre for Taxonomic Studies
St Joseph's College
P O Box 5031
Bangalore - 560 001

Dr S K Saxena
Central Arid Zone Research Institute
Jodhpur - 342 003

Mr Ramit Sethi
Standard Chartered Bank
DLF Centre (4th floor)
Sansad Marg
New Delhi - 110 001

Dr (Mrs) M Sharma
Department of Biotechnology
Block 2 (7th floor)
C G O Complex, Lodhi Road
New Delhi - 110 002

Dr J D Sharma
Environmental Occupational Health
School of Environmental Sciences
Jawaharlal Nehru University
New Delhi - 110 067

Ms V Shiva
105 Rajpur Road
Dehra Dun - 248 001

Dr N A Siddiqui
Aga Khan Foundation
Sarojini House (2nd floor)
G Bhagwan Das Road
New Delhi - 110 001

Dr R Singh
Rajasthan Agricultural University
Jaipur

Mr S Singh
Ministry of Environment and Forests
Paryavaran Bhawan
C G O Complex, Lodhi Road
New Delhi - 110 003

Mr D Singh
The Pioneer
Link House (2nd floor)
3 Bahadur Shah Zafar Marg
New Delhi - 110 002

Mr Kartar Singh
British Council Division
British Deputy High Commission
737 Anna Salai
Madras - 600 002

Mr N Singh
Ministry of Environment and Forests
Paryavaran Bhawan
C G O Complex, Lodhi Road
New Delhi - 110 003

Ms J Singh
British High Commission
Chanakyapuri
New Delhi - 110 021

Prof. S Singh
Indian Institute of Public Administration
Indraprastha Estate
New Delhi - 110 002

Dr V V Srinivasan
Director
Institute of Wood Science and Technology
Malleswaram
Bangalore - 560 003

Dr K N Subramanian
Institute of Forest Gentics and Plant Breeding
P O Box 1061
Coimbatore - 641 002

Mr Shyam Sunder
Karnataka State Forest Department
2989/D 12th Main
HAL II Stage
Bangalore - 560 008

Mr N Suresh
The Times of India
7 Bahadurshah Zafar Marg
New Delhi - 110 002

Mrs Kitty Tawakley
Information Section
British High Commission
Chanakyapuri
New Delhi - 110 021

Dr D N Tewari
Indian Council of Forestry Research and Education
Dehra Dun - 248 006

Dr J Cloudsley-Thompson
10 Bagtishill Street
London N1 1TE

Mr C L Trisal
Ministry of Environment and Forests
Paryavaran Bhawan
C G O Complex, Lodhi Road
New Delhi - 110 003

Mr G Varughese
Development Alternatives
B-32 Institutional Area
TARA Crescent
New Mehrauli Road
New Delhi - 110 016

Dr J Venkateswarlu
Central Arid Zone Research Institute
Jodhpur - 342 003

Dr (Mrs) L Vijayan
Salim Ali Centre for Ornithology and Natural History
Coimbatore - 641 010

Dr V S Vijayan
Salim Ali Centre for Ornithology and Natural History
Coimbatore - 641 010

Dr M Walkey
The Durrell Institute of Conservation and Ecology
University of Kent
Canterbury, Kent
Great Britain CT2 7NX

Mr J Winter
Development Section
British High Commission
Chanakyapuri
New Delhi - 110 021